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The 400,000 lb per hr high-pressure steam generating unit at Reeves Avenue Station, Richmond, Va., nears completion

Steam Generation at Glendale ▶

Coal Handling for Central Stations ▶

Elesco Superheater with elements connected to headers by ball joints.

Elesco Girth Superheater designed for hrt boilers.

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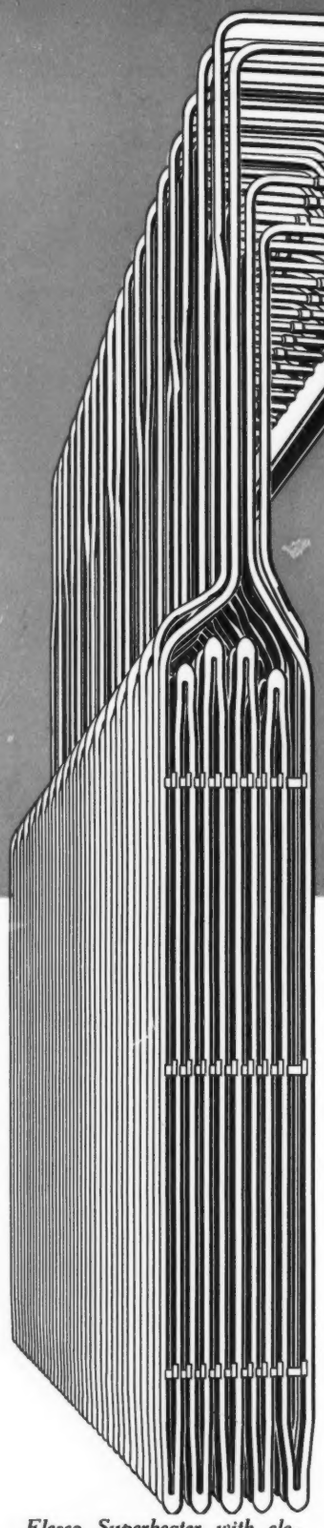

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME THIRTEEN NUMBER ONE

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Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Avenue, New York
A SUBSIDIARY OF COMBUSTION ENGINEERING COMPANY, INC.

Frederic A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Secretary and Treasurer.

COMBUSTION is sent gratis to engineers in charge of steam plants from 500 rated boiler horsepower up and to consulting and designing engineers in this field. To others the subscription rate, including postage, is $2 in the United States, $2.50 in Canada and Great Britain and $3 in other countries. Single copies: 25 cents.
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Issued the middle of the month of publication.

Publication office, 200 Madison Ave., New York CCA Member of the Controlled Circulation Audit, Inc.

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EDITORIAL

Employment and Earnings of Engineers

The Bureau of Labor Statistics of the U. S. Department of Labor has just issued a 235-page bulletin giving the results of a comprehensive survey of employment and earnings in the engineering profession from 1929 to 1934, the survey having been made in 1935 at the request of American Engineering Council. The findings are based on complete information supplied by more than fifty thousand engineers out of three times that number to whom questionnaires were mailed.

A vast amount of work was apparently involved in compiling and digesting the returns, which fact may have been partly responsible for the long delay in making the results available. While the survey presents for the first time a substantially reliable picture of the unemployment and reduced earnings of engineers during the worst years of the depression, it is unfortunate, for the purpose of comparison, that it did not also cover a normal period.

Although few, if any, of the actual figures presented are now applicable, in view of changed economic conditions, certain basic relations were revealed that may have more or less permanent bearing. For instance, the earnings of the upper ten per cent in each age group advanced more rapidly than the median earnings, whereas the level of earnings of the lowest ten per cent, at a given age, advanced less rapidly than the median level and reached a maximum at an earlier age; that is, the earnings of the lowest ten per cent did not advance significantly beyond forty years of age. On the other hand, average earnings increased with length of service and experience up to the 60- to 65-year group. In the 40- to 47-year group the upper ten per cent of those engaged in non-engineering work earned substantially more than the upper ten per cent in strictly engineering work.

In 1929 mechanical engineers averaged higher earnings than electrical or civil engineers, although during the depression years the median earnings of mechanical engineers declined 37.2 per cent, compared with 33 per cent for all engineers.

Those with engineering degrees averaged higher incomes than those without a degree during the first few years of employment, after which there was little difference for a period, but among the older age groups the spread in favor of those with technical training was marked.

With reference to educational qualifications, a distinct increase in post-graduate work was apparent. Among 1905 graduates this was only 6.6 per cent; by 1910–1914 it was 7.1 per cent and 10.2 per cent for those graduating between 1925 and 1929.

While this analysis has reference value and might prove very useful should we be faced by another depression, its value for normal conditions is limited; also, changing economic conditions make it difficult to conduct such a comprehensive survey and digest the results in a sufficiently short period to be of maximum use. It is suggested that the Bureau of Labor Statistics might find it possible to make a limited survey, perhaps every five years, which would suffice to present a representative cross-section of the prevailing situation in the engineering profession and be made available in a reasonably brief time.

That the Bureau is conscious of the importance of the engineering profession in the general economic set-up, is indicated by the following excerpt from the preface of the report in which Isador Lubin, Commissioner of Labor Statistics, observes, "It is obvious from this study that problems of earnings and employment opportunity are by no means confined to wage workers and that the Department of Labor must be concerned with other groups whose income depends upon the sale of their services. The 'labor problem,' if it ever was primarily the problem of a special class in the community, has become in one way or another the problem of virtually all groups."

Inventions for Defense

With the purpose of encouraging the public to submit inventions or inventive ideas of defensive value, the Government, through the Department of Commerce, early last fall set up a National Inventors Council. This is composed of a group of outstanding scientists and industrialists with wide experience in the development and utilization of inventions, assisted by a staff of engineers and technical committees whose function is to serve as a clearing house for the ideas submitted and pass along those of potential value to the proper military and naval bureaus. It will be recalled that a similar body was set up during the World War.

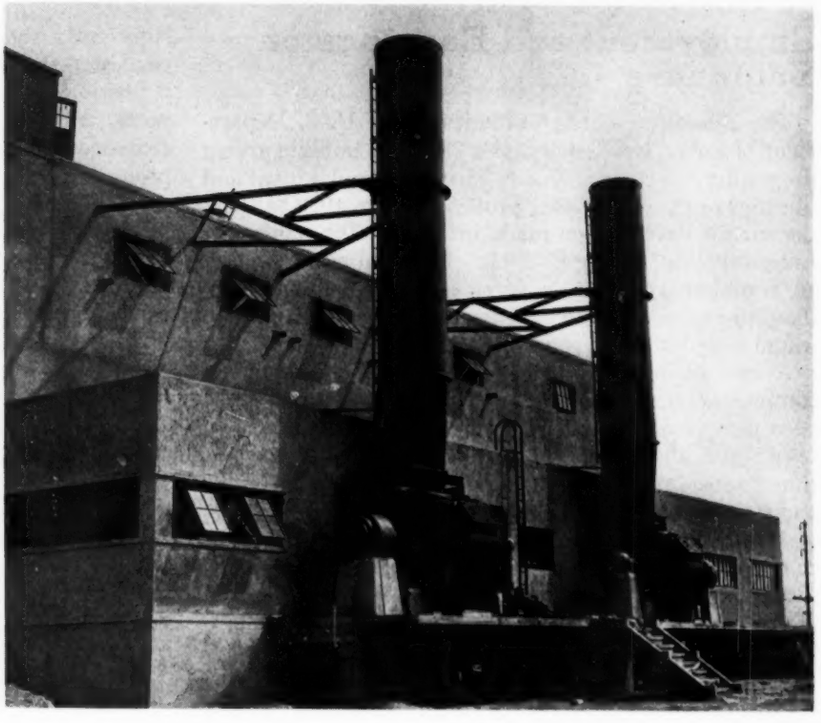
The Council reports that during its first six months approximately thirty thousand communications were received of which about sixteen thousand contained inventive ideas. Of these, a considerable number possessed sufficient merit to warrant serious consideration and some have already been accepted for use by the Army and Navy.

This is both surprising and encouraging, for usually worth-while inventions grow out of systematic research and development or are the product of inventive genius reinforced by basic knowledge in the particular field of application. Aside from gadgets, few modern useful inventions have resulted without such background.

However, the present war in Europe has revealed many surprises and innovations in military tactics and matériel, to combat which new methods and devices become necessary. Bearing in mind that many of our most useful items of military equipment have been devised by civilians, it is well that the submission of new ideas, based on sound conceptions, are being solicited and that a well-qualified body has been set up to give them proper consideration.

STEAM GENERATING UNITS at the GLENDALE POWER PLANT

By O. H. HEDRICH,
Mechanical Engineer
Public Service Dept.,
Glendale, Calif.



Exterior view of Glendale plant showing induced-draft fans and stub stacks

This plant, designed to operate in conjunction with hydro power from Boulder Dam, required provision for very rapid load pickup, which condition was met by providing excess design pressure, oversize steam drums and oversize draft and fuel burning equipment. Two 20,000-lb per hr units are installed and operate normally at 600 lb, 825 F. The supporting structure was especially designed to resist earthquake shocks.

IN 1938 the Public Service Department of Glendale, Calif., undertook economic studies in connection with the construction of an oil-and gas-fired steam-electric generating plant of 20,000 kw capacity to serve as a standby, regulating and peak-knocking plant to operate in conjunction with the supply of hydroelectric power transmitted from Boulder Dam. In view of these conditions it was necessary that the boilers be designed for rapid load pickup which involved a number of rather unusual features such as excess design pressure, oversize draft and fuel-burning equipment, large steam drums (to provide increased steam-releasing surface), over-size superheaters and low nominal heat release. Also, because of the fuel and probable load conditions, it was deemed desirable to provide a bypass around the air preheater to eliminate sulphur corrosion at low ratings.

As a result of the studies and to meet the foregoing conditions, two oil- and gas-fired Combustion Engineering steam generating units of the two-drum VU type were ordered in October 1939. These have the following characteristics:

Nominal operating pressure, 600 lb per sq in. gage
Maximum design pressure, 750 lb per sq in. gage
Nominal operating steam temperature, 825 F, plus or minus 10 deg F
Nominal steam output of each unit, 200,000 lb per hr
Nominal feedwater temperature, 400 F
Furnace volume, 7750 cu ft
Nominal heat release, 33,500 Btu per cu ft per hr

Discussing the operating conditions in order, the relatively high design pressure is most interesting. For the particular boilers in question there was very little difference in design whether they were built for 600 or 750 lb pressure. Refractory, burners, fans, air heaters, foundations, supporting steel, valves and appurtenances were the same for either pressure. This was also true for the pressure parts of the boiler except for the drums. Therefore, the increased cost of designing for 750 lb instead of 600 lb was only three per cent of the overall cost and resulted in a very distinct and desirable operating advantage.

At low loads the pressure is maintained as high as practicable—in the neighborhood of 730 lb at the drum. Then in the event of a sudden steam demand such as

would result from the loss of a transmission tie line, it is possible to take a pressure drop of as much as 100 lb without falling below the standard steam conditions at the turbine throttle. The time during which this pressure drop occurs makes it easily possible to increase the firing rate so that full load steam flow may be maintained without dropping below 600 lb which is required at the turbine throttle to develop full rated capacity.

Another advantage of operating at an over pressure during floating load conditions is that the output of the constant-speed centrifugal feed pumps drops off as the drum pressure rises and increased throttling due to increased excess feedwater pressure is obviated. In fact, it is theoretically possible to control the feedwater flow to the boilers without regulation of feed valves by simply raising the drum pressure as the steam flow drops. However, such control is not accurate enough for practical working conditions, but there is no question as to the excess feedwater pressure being kept practically constant for all rates of flow. This avoids the extreme throttling necessary at low flows which occurs if the drum pressure or superheater outlet pressure is kept constant.

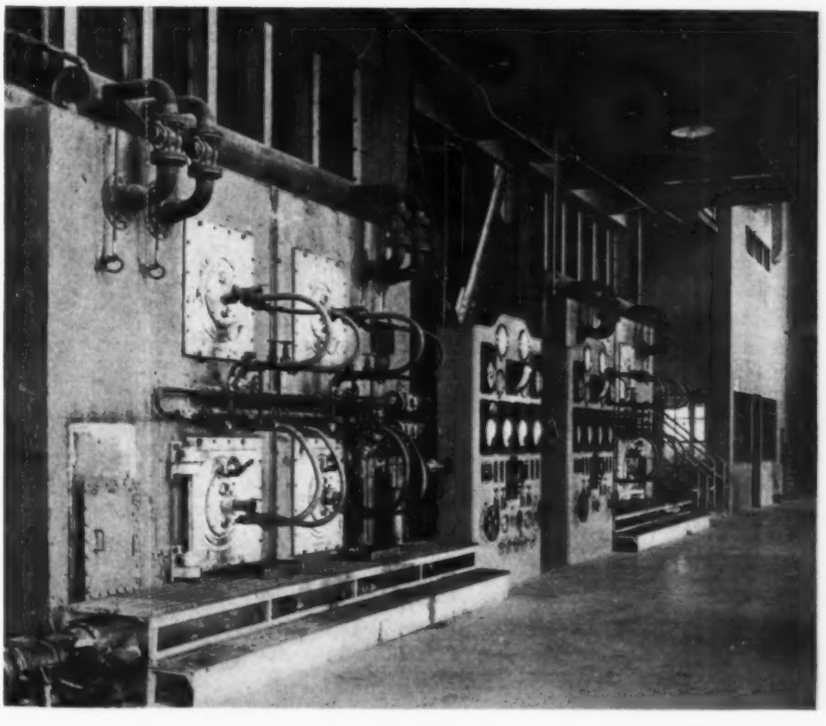
Over-Capacity Fans and Fuel Burners Aid Rapid Load Pickup

Realizing the need for extraordinary rates of heat release for sudden load pickup, both the forced- and induced-draft fans and the fuel burners (combination oil and gas) were purchased to handle 40 per cent more air and fuel than is necessary to develop full rated steam output of 200,000 lb per hr for each unit. This extra capacity goes far toward overcoming the inherent time lag normally prevailing between the instant the fires are increased and the first indication of increased steam flow.

The gas burners are more or less conventional and permit of a complete range of 10 to 140 per cent steam flow by simple throttling of a master header valve which controls all four burners on each boiler. The oil burners involve a somewhat more complicated return oil system which gives a burning range of from 500 to 20,000 lb of oil per hr with all four burners in operation at all times regardless of load. This is vitally important in a plant which may be floating on the line at practically no load and suddenly be called on to develop full load in a period of one to two minutes. Pickup of this order does not allow time enough to place additional burners in service, and the ability to increase the fires almost instantaneously is of inestimable value. The accompanying diagram illustrates the piping arrangement. Note in particular the differential pump which maintains a constant excess head between the supply and return oil-burner headers. Complete load range is accomplished through operation of one master valve and fineness of atomization of the oil is kept constant regardless of load, resulting in smokeless combustion without carbon formation within the furnace.

At maximum fuel burning rates the furnace heat release is in the order of 47,00 Btu per cu ft per hr. Completely water-cooled walls, as well as the top and bottom of the furnace, adequately protect the refractory at this combustion rate and, being of the bare-tube type, they aid materially in speed of load pickup due to the large amount of radiant heat absorption surface presented to the fire.

Another design feature provided to facilitate rapid load pickup is the extra large superheater. The boiler specifications called for a superheater sufficiently large to maintain 825 F plus or minus 10 deg F at all steam flows greater than 40 per cent of the nominal rated flow of 200,000 lb per hr. This was necessary because of the demands of the turbine manufacturer that the throttle steam temperature be kept as nearly constant as possible at all loads in order to prevent differential expansion difficulties with rapid load changes. The superheater was guaranteed to produce steam at 675 F at 20,000 lb per hr (10 per cent nominal load) and maintain 825 F at flows above 80,000 lb per hr (40 per cent nominal load). Actually, the performance has exceeded these guarantees. Control is accomplished electrically by motor-operated dampers which bypass part of the products of combustion around the superheater through an idle pass. Due to the greater volume of the gases of combustion, design temperature is maintained at a some-



Firing Aisle and Boiler Control Panel

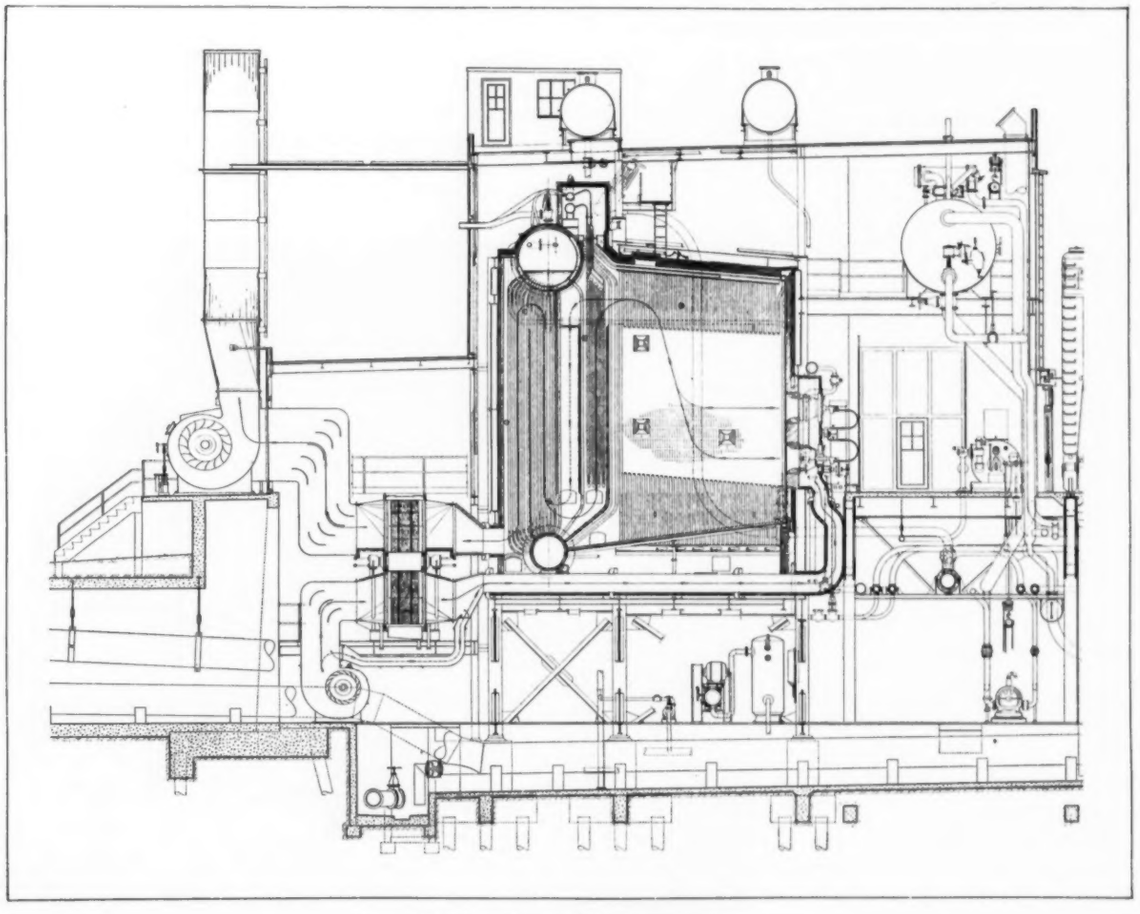
what lower steam flow when gas fuel is burned than when oil is burned.

No economizers are used but a large air preheater of the regenerative type, located at the rear of each unit gives a combustion air temperature of the order of 450 F at nominal full load with a stack temperature of 330 F. The size of the heater to develop these temperatures would result in a final stack temperature below 260 F at steam flows of less than 20,000 lb per hr. Since temperatures less than 260 F may result in condensation of sulphurous acid gas in the stack (which is of unlined steel plate) it was necessary that a bypass duct on the air side of the preheater be provided. When the damper in this bypass duct is adjusted properly, suitably high stack temperatures may be easily maintained at very low boiler loads.

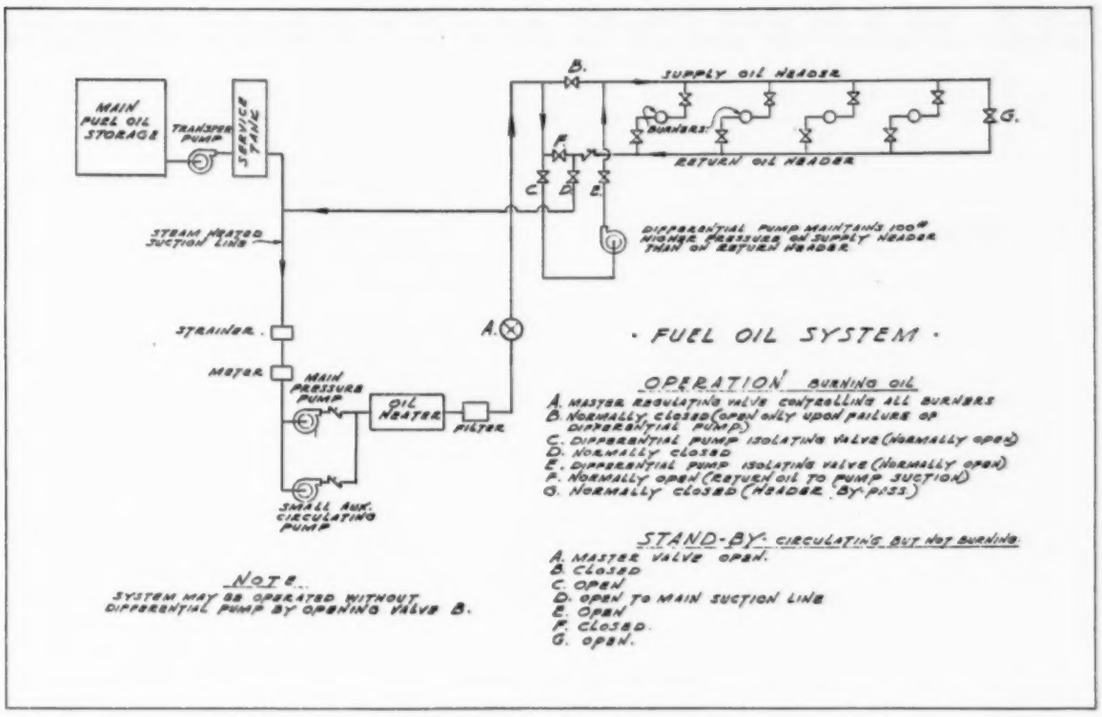
Both the forced- and the induced-draft fans are of the double-width, double-inlet type and are driven by two squirrel-cage motors of different speed and horsepower ratings. Air and gas flows are controlled by means of radial type louvres placed in the fan inlets and operated by a compressed air servo-motor. The forced-draft fan is located in the boiler basement but the induced-draft fan is located outside the building enclosure, and elevated on a concrete balcony to prevent any operating interference from surface water which may surround the plant. It will be noted that the induced-draft fan is at the firing aisle level and that the stub stacks are supported directly on the fan housing. The fans, air heater and boiler are compactly arranged to provide a minimum of breeching duct length and consequent minimum friction and radiation loss.

Supporting Structure Designed to Resist Earthquake Shocks

The steam generator and air preheaters are supported on a steel framework entirely separated from the building frame, and this frame is braced to withstand a horizontal load of 50 per cent of the vertical load at any elevation in the structure. This high lateral stress factor was provided to prevent possible damage due to earthquakes which have been not uncommon in this section of the country. Most modern buildings are braced for 20 per cent lateral force which is considered sufficient to prevent collapse, but these boiler frames were braced for 50 per cent gravity load on the theory that such construction would not only prevent collapse but would also prevent cracking and falling out of refractory, which latter might prove extremely serious if an earthquake happened to occur at a time when a heavy load and consequent large fires were being carried. Carrying out this idea, all refractories are sectionally supported, each row of tile being supported on Z-bars and cast-iron hangers, securely bolted to the boiler framework. Column footings are provided in the form of massive concrete pile cap slabs which, in turn, are supported on 35-ft steel-cased poured concrete piling. Random piles were tested to 150 tons load with a total settlement of 0.34 in. Actual design



Section through boiler plant



Layout of fuel-oil system

loading of the piling was 45 tons with an average permanent settlement of 0.08 in.

All High-Pressure Piping Welded

All piping connecting to the boilers, superheaters and appurtenances was designed for 900 lb operation and was completely welded including the steam delivery pipe, non-return globes and shut-off gate valves. Saturated steam is taken off through a series of tubes spaced throughout the drum length and welded to the saturated superheater header. Superheater elements are welded to both the saturated and the superheater headers, no hand holes or tube access openings being provided in the units.

At the present time the steam generators are manually operated by a remote control compressed air system, which may be easily converted at any future time to complete automatic combustion and feedwater control. Duplicate mechanically operated fuel and feedwater control valves are provided. All instruments, recording and indicating, together with all motor, damper and valve controls are located on a firing aisle panel at the front of each boiler.

The accompanying cross-section of the boiler plant gives a general idea of construction arrangement. The overall height of the plant was limited to 45 ft above grade because of the presence of a closely adjacent airport. Adequate basement head room has been provided to permit the installation of ash-removal apparatus in the event that pulverized-coal firing should become desirable at some future time.

The plant has been in operation since February 1941, and while formal efficiency tests have not yet been completed, all expectations as to operating performance have been realized to date.

Carbonaceous Cation and Anion Exchangers in Water Treatment

In a report just issued by the Bureau of Mines (No. 3571) S. J. Broderick reviews all available information on carbonaceous exchangers and the progress that is being made in their use. He makes the following observations in the introduction:

"The discovery in 1934 that carbonaceous materials, such as coal peat and lignite, when treated with concentrated sulfuric acid, were given cation or base-exchange properties opened up a field of new materials with many interesting possibilities. These hydrogen exchangers, as they were called, were so superior to the impractical hydrogen exchangers made from natural and synthetic zeolites that they were accepted immediately by the water-conditioning industry. A noteworthy advantage of the carbonaceous exchangers is that they are nonsiliceous, hence they do not give up silica to the water as do the natural and synthetic zeolites, especially if the hard water is corrosive.

"In the same year (1934) anionic exchangers were introduced. Adams and Holmes, working in England, produced synthetic organic resins that were anion exchangers and could be used to remove negative radicals from hard waters. This discovery and that of carbonaceous cation exchangers furnished the water-purification industry with new agents, superior in some respects to the older ones, with which results could be accomplished that were impossible with other available materials. For example, an equivalent of "distilled water" can be made with cation and anion exchangers more cheaply than by the customary method of distillation, provided the raw water does not have too high a content of solids. The ordinary hard water is passed through a hydrogen exchanger to remove the cations and thence through an anion exchanger to remove the negative radicals, thus producing the equivalent of a distilled water except for the silica content which is not removed."

COAL HANDLING for Central Stations

By GEORGE C. DANIELS
Mechanical Engineer
The Commonwealth & Southern Corp.

Excerpts of a paper contributed by the Fuels Division at the Semi-Annual Meeting of the A.S.M.E. at Kansas City, Mo., June 16–19, 1941, in which the author reviews and compares the various systems in use, cites current trends, and gives initial and operating costs for fourteen different installations.

THE economical handling of coal to insure an uninterrupted supply to the boilers is one of the major problems in the design of central stations and differs from most other design problems in the great number of variables which exist and the numerous combinations of equipment and methods which can be used. The method of receiving the coal at the plant is usually one of the deciding factors in the general layout. If coal is received by water in large lake or ocean-going vessels, rapid unloading facilities are necessary in order to avoid demurrage. For this purpose movable towers with large grab buckets are used. For river transportation, open coal barges are used, and it is the general practice to use stationary unloading towers with grab buckets for unloading. On the Great Lakes, the use of self-unloading vessels is becoming more prevalent and this materially reduces the coal-handling equipment required.

Some central stations are located at the mouth of the mine and receive their coal directly from the mine in mine cars. Coal received by rail generally comes in hopper-bottom dump cars, but in some localities coal is shipped in flat-bottom cars which may or may not be provided with dump bottoms. Such cars must be unloaded with a grab bucket or by means of a car dumper. Delivery by truck from near-by mines is becoming more prevalent, and provisions for such delivery have been made at many of the plants.

Trends in Coal-Handling Methods

With the increasing market for coal for household stokers and with the increasing use of pulverized fuel in central stations, the size of coal that is being used by many central stations has decreased from $1^1/_8$-in. screenings to $^3/_8$-in. screenings or less. The use of fine coal has resulted in greatly increasing the time required to unload hopper-bottom cars, especially if the coal is wet, so that the coal-handling capacity in those plants which obtain their coal in hopper-bottom cars and unload by gravity into a pit may be seriously reduced. The packing of the fine coal in the bunkers has presented a serious problem which has not been adequately solved.

The use of bulldozers for compacting coal piles has been employed for at least 15 years, and has recently become quite common. This has resulted in practically eliminating any danger from spontaneous combustion. Consequently, the necessity for using storage and reclaiming equipment, having large digging capacity to dig out fires in the coal-storage pile, has been eliminated with a corresponding saving in initial investment. The use of the bulldozer for moving coal short distances and the addition of a carryall to the bulldozer to move coal over considerable distances is finding increased favor. With this equipment, the initial investment is very low, and it has the advantage that capacity can be increased readily by additional units.

Comparison of Coal-Handling Costs for Various Systems

A comparison of coal-handling costs for a number of different coal-handling systems is shown in the table.

The low load factor of coal-handling equipment is due to several reasons. The capacity of the equipment is normally designed to provide for future increases in coal consumption, if not for the ultimate size. In order to allow time for repairing breakdowns, the capacity must be sufficient to coal the plant at maximum load in at least two of the three shifts per day, and it is usually figured to do so in one shift of 8 hours. Thus, for a central station having a yearly load factor of 60 per cent, the load factor on the coal-handling equipment would be 20 per cent to allow the plant to be fueled in 8 hr of continuous operation of the coal-handling equipment at its full capacity. Since coal-handling equipment can seldom be operated continuously at full capacity, due to the delays in spotting boats or cars, to difficulties encountered with the functioning of the equipment, or to foreign matter in the coal, the load factor will be somewhat lower than that just indicated if the fueling of the plant is to be accomplished in an eight-hour shift. The average load factor on the coal-handling equipment for the plants listed is 14.6 per cent.

Maintenance costs should be averaged over a period of years so that the complete maintenance cycle is represented. Some of the plants listed have so recently been installed that the maintenance is unduly low, while other plants may have had unduly high maintenance costs for the period which is represented by the data. However, the average maintenance cost of 3.6 cents per ton for the plants listed is believed to be fairly representative for coal-handling equipment in central stations.

Operating labor, given in the table, shows an average of 6.7 cents per ton for thirteen plants, which is roughly twice that of the average maintenance cost. The operating costs are more affected by the type of equipment used than appears to be the case with maintenance. Those plants, receiving their coal in hopper-bottom cars and

unloading by gravity into a pit, show an operating labor cost varying between 6.1 cents and 10.1 cents per ton and averaging 7.8 cents per ton. Those plants, using grab buckets for unloading either from coal barges or from flat-bottom coal cars, show an operating cost of from 4 cents to 5.3 cents per ton, averaging 4.7 cents per ton. It should be noted that the table does not include any systems using car dumpers or car unloaders which would be expected to have lower operating labor costs, but several plants not listed using car dumpers show total maintenance and operating labor costs varying from 6 cents to 10 cents per ton, which is somewhat lower than the average of 10.6 cents per ton given.

The cost of power, which varies from several kilowatthours to a fraction of a kilowatthour per ton of coal handled, and the cost of lubricants have not been included in the operating costs, but these items are usually small in comparison with the other costs.

Fixed Charges on Coal-Handling Equipment

It will be noted that the fixed charges, which have arbitrarily been assumed to be 12 per cent per annum on the investment, are considerably in excess of the operating costs in all except three of the stations. The low fixed charges in these three stations of small coal-handling capacity are partly due to their requiring but little equipment for handling coal to and from their emergency storage; but nevertheless it indicates that, depending upon the rapidity of the growth of the plant, it may be more economical to install relatively low-cost, small-capacity, coal-handling equipment for the initial installation which can later be replaced by equipment capable of meeting the requirements of the enlarged or ultimate plant than to design the original coal-handling equipment for the ultimate plant. The usual economic analysis must, however, be supplemented by considerations of the continuity of coal deliveries, reliability and operating-personnel requirements.

The fixed charges on coal-handling equipment for plants using water-borne coal, received in large lake or ocean-going vessels, are usually high on account of the large-capacity unloading equipment required to avoid payment of demurrage and on account of extensive storage-handling equipment.

The average of the fixed charges for the fourteen plants listed is 27 cents per ton of coal burned, which is 2.6 times as great as the combined maintenance and operating-labor costs of 10.3 cents per ton.

Use of Bulldozer and Carryall

The high fixed charges for central-station coal-handling systems are partly due to the extensive storage-handling facilities required. In addition to the temporary coal storage that must be provided at some plants where the coal delivery is intermittent, practically all stations keep a permanent storage which is usually large enough for several months' supply. It is in this equipment that the greatest reduction in investment can be made. The use of bulldozers and carryalls is finding increased favor for handling storage coal. For short distances, up to approximately 150 ft, the bulldozer by itself may be used economically, while for distances beyond this a carryall in combination with the bulldozer is used.

The bulldozer consists of a caterpillar tractor with a blade somewhat wider than the tractor and at right angles to the tractor center line, which can be adjusted vertically. The angledozer is similar except that the blade can be set at an angle and also adjusted vertically. The operation of the carryall, which is attached to the bulldozer or angledozer, is controlled by the operator of the tractor and it can load or dump quickly or at a uniform rate as it moves along. The coal-handling capacity of the carryall varies with the size of the equipment and the distance hauled. Thus with a 10-ton-capacity carryall, hauling 300 ft, the handling capacity would be approximately 120 tons per hr. For twice the distance, the capacity would be approximately 90 tons per hour. Records available indicate that the overall

TABLE OF COMPARISON OF COAL-HANDLING COSTS

Coal Delivered by Water, Rail or Truck	Year Installed	Capacity to Bunkers, Tons per Hour	Cost of Installation Including Docks, Tracks, Pits, Cranes, Conveyors, etc.	Years Represented by Data	Tons per Year	Load Factor	Maintenance Cost, Cents per Ton	Operating Labor, Cents per Ton	Total Operating Costs, Cents per Ton	Fixed Charges, Cents per Ton	Total Fixed and Operating Costs, Cents per Ton	Description of System
W	1939	400	$691,000	1940	124,000	3.5	1.3	5.0	6.3	67.0	73.3	Coal delivered on dock by self-unloading lake boats, gantry crane to storage or to belt conveyors to plant
W	1925	350	1,220,000	1937–39	382,046	12.5	5.3	7.6	12.9	38.1	51.0	Gantry crane from lake boats to storage, or by car and belt conveyor to plant. Auxiliary drag line storage
W	1926	250	655,000	1938–40	547,574	25.0	4.2	4.0	8.2	14.4	22.6	Clam shell from river barges to belt conveyors to plant or to Lidgerwood storage
W	1928	125	978,000	1935–40	175,879	16.1	4.8	6.6	11.4	66.8	78.2	Clam shell from ocean steamers or barges to belt conveyors, to plant or to drag line storage
R	1939	200	360,000	1940	196,000	11.2	0.7	6.1	6.8	22.0	28.8	Cars discharge by gravity into pit, to belt conveyors, to plant or to drag line storage
R & T	1939	125	160,000	1940	122,924	11.2	4.5	6.4	10.9	15.8	26.7	From cars by gravity to pit, to belt and bucket elevator, to drag line storage or to plant by belt
R	1936	100	212,000	1940	79,360	9.1	1.9	7.5	9.4	32.0	41.4	From cars by gravity to pit, to belt and bucket elevator, to drag line storage or to plant by belt
R	1913	75	66,000	1936–38	109,000	16.7	2.4	5.3	7.7	7.3	15.0	Stationary tower with clam shell bucket from cars to distributing belt. Locomotive crane for storage
R	1925	75	112,000	1936–38	217,588	33.0	2.1	4.4	6.5	6.3	12.8	Locomotive crane with bucket unloads cars to pit, to chain and bucket elevator, to scraper conveyor. Locomotive crane for storage
R	1927	60	160,000	1938–40	62,606	11.9	6.1	9.8	15.9	30.7	46.6	Cars discharge by gravity into pit, to belt and bucket elevator, to scraper conveyor. Locomotive crane for storage
R	1928	60	164,000	1937–39	43,860	8.3	4.9	10.1	15.0	45.6	60.6	Cars discharge by gravity into pit, to belt and bucket elevator, to scraper conveyor. Bridge crane for storage
R	1926	50	97,000	1937–39	54,636	12.4	4.8	8.1	12.9	21.5	34.4	Cars discharge by gravity into pit, to belt and bucket elevator, to scraper conveyor. Bridge crane for storage
R	1920	40	20,000	1939–40	40,077	11.4	3.4	6.7	10.1	6.0	16.1	Cars discharge by gravity to shallow pit, to inclined scraper conveyor, to bunkers. Storage by portable conveyor
R	1937	150	185,000	1940	275,376	21.0	...	..	10.6	8.1	18.7	Cars dump into pit, to skip hoists, to belt distributors. Storage by locomotive crane and bulldozer
					Average	14.6	3.6	6.7	10.3	27.2	37.6	

cost of handling coal by this method, including operating labor, maintenance, fuel, lubricants and depreciation, does not exceed 5 cents per ton.

Small bulldozers for compacting coal have been in use for many years. Their action in compacting coal is not by compression alone, but by thoroughly mixing the coal and depositing it in layers 6 in. to 12 in. thick, the fine coal filling the voids between the larger lumps.

It is well established that spontaneous combustion occurs in coal piles if the air circulated through the pile is insufficient to keep it cool but sufficient to support combustion. This condition exists when coal is stored by the usual methods which tend to segregate the coal. Any attempt to compress the pile after it has been built up is futile. Excluding the air by water or by covering the pile is expensive and adds to the difficulty of reclaiming. Some coals are more subject to spontaneous combustion than others, but all kinds of coal have been successfully stored when compacted by bulldozers. Screenings or crushed coal can be compacted better than sized coal which does not have the fines to fill the voids.

Car-Unloading Methods

The capacity of the coal-handling equipment when receiving coal by rail is fixed largely by the speed at which cars can be emptied, which again is determined by the size of the coal, by whether it is wet or dry, and by the type of cars. There are some localities in which coal is received in hopper-bottom dump cars only. Other localities may obtain coal in flat-bottom cars only or in cars of several varieties. A grab bucket is ideal to use for flat-bottom cars, but not for hopper-bottom cars nor for cars with cross braces.

When using a $1^1/_2$-cu yd grab bucket with a locomotive crane or overhead bridge, a 50-ton flat-bottom car can be unloaded in approximately 20 min. Allowing time for switching the cars, the unloading capacity would probably not exceed 100 tons per hr continuously, and one man would be required on the crane and one man in the car.

When dumping free-flowing coal from 70-ton hopper-bottom cars into a pit of ample size and length to dump the entire car at one setting, the average unloading speed including switching will be approximately 200 tons per hour. Fine coal $^3/_8$ in. and less, when wet, will reduce the speed of unloading even with four men in the car to 100 tons per hour or less.

The reliable capacity of either of the foregoing methods for unloading screenings of $^3/_8$ in. and smaller, when wet, is approximately the same and is not much in excess of 100 tons per hour. For elevating coal at this capacity, various types of equipment are used such as belts or chains with buckets, skip hoists and occasionally inclined belts.

Reliable capacities over 100 tons per hour when handling fine screenings, especially when wet, must be obtained by means of car unloaders or car dumpers. With a recently developed "accelerator" for unloading hopper-bottom cars, the dump gates in the car are opened and the accelerator screws are revolved, digging themselves into the coal until the bottom of the car is reached, whereupon the screws are reversed to expedite the flow of coal. With this device two 70-ton cars are unloaded per hour, with one operator and one or two clean-up men in the car, when unloading into a small-capacity track hopper. With a large track hopper, permitting continuous operation of the accelerator, a 70-ton car can be unloaded in 20 min. The accelerator is fairly efficient in handling frozen coal, provided the coal surrounding the hopper doors is removed by hand or some other means.

Another type of car unloader which has been in use for several decades consists of an overhead crane carrying heavy spuds approximately the width of the car and a large air-operated jack hammer. The coal is moved toward the car openings with the spuds after the jack hammer has made openings through tightly packed coal above the car hoppers. The jack hammer is especially valuable in breaking up frozen coal. This equipment can also be used to move cars, which is a decided advantage. With a crew of four men, one operating the unloader, cars are unloaded and shoveled clean at the rate of one 70-ton car every 10 min, even with wet $^3/_8$-in. slack.

Capacities greater than those mentioned must be obtained by means of car dumpers which, with two men, will unload coal cars of any size and kind at the rate of one every three or four minutes. Frozen cars of coal present a difficult problem and cannot be handled with the car dumper unless they are previously thawed out or the coal is broken up.

Elevating coal at large capacities is generally accomplished with inclined belts, the cost of which does not increase as rapidly as their carrying capacity increases so that the capacity is determined by the car-unloading speed or other considerations.

For conveying and distributing coal over the bunkers, belts with traveling trippers are very generally used, especially for the larger capacities, although the use of scrapers or flight conveyors is becoming common even for large capacities. The use of rivetless chains instead of roller chains for flight conveyors is becoming more prevalent. To obtain roller chains with a strength equal to the rivetless type, it is necessary to select chains, especially for the large capacities, with about 4 times the weight per foot so that the effect of low frictional resistance is lost in the added pull due to the chain weight. The chief maintenance of scraper conveyors is the trough linings which can be designed for easy replacement.

Eliminating Dust

The elimination of dust in coal handling has recently been receiving attention from central-station operators. The practice of The Commonwealth & Southern Corporation Engineering Department in this regard may be of interest. The top of the coal bunkers is sealed with a floor and a slight suction is maintained in the bunkers with an exhaust fan. This not only removes the air displaced by the coal but also induces a flow of air into the bunkers through the conveying system or distributors. A dust collector on the fan discharge was found to be unnecessary on account of the insignificant amount of dust collected. Flight conveyors can readily be totally enclosed.

Practically no dust rises from the coal carried on conveyors if protected from strong air currents, except at the loading points or on the return. At the return, an efficient belt scraper is provided, discharging into an enclosed hopper or chute. Loading chutes and coal feeders are provided with dust-tight enclosures. At the dis-

charge end of the chutes where the coal is delivered to a belt or feeder, a slight suction is maintained which effectually keeps the dust from emerging. A small fan and cyclone separator, discharging back into the coal stream, may be provided at each transition point, or a single fan with one or more cyclone separators can be used for several transition points.

With a dust-free coal-conveying system, the top of the bunkers need not be walled off from the boiler room, thus admitting more light and air. In addition, the conveyor galleries, coal pits, crusher room, etc., can more easily be inspected and maintained without discomfort to the operators and janitor labor can be noticeably reduced.

Coal crushers are an important link in any coal-handling system for central stations. With the use of bulldozers for compacting and moving storage coal, it is advisable to be able to crush the coal for storage as well as for the bunkers. Large-capacity nonclogging screens ahead of any crusher serve to prevent the clogging of the crusher when handling wet coal carrying a large amount of fines. Foreign matter such as sticks, iron or rags continues to be troublesome, except with the Bradford type of coal breaker, which is usually used for large capacities and is finding favor even in capacities as low as 200 tons per hour. Trouble from straw which is used to seal the bottom of coal cars is frequent in some localities. After passing through a Bradford breaker, the straw is well dispersed through the coal, but with the ordinary crusher the straw may be bunched and cause trouble in the plant. The removal of the straw is accomplished in some plants by passing the crushed coal through a coarse-mesh rotating screen.

Moving and Spotting Coal Cars

The moving and spotting of cars for those plants receiving their coal by rail is a problem that merits careful attention. Much time and labor may be consumed with inadequate facilities and a balance between fixed charges, operating costs and adequate capacity must be reached. The problem begins with the track layout, including switches, track curvatures and grades. The use of a winch for pulling cars is very general but usually it is not entirely satisfactory. If the winch is large enough to pull a string of cars, it is hard on the railroad equipment, and a smaller retrieving winch is necessary to retrieve the heavy pulling cable or an endless cable must be used. To spot the cars over the unloading pit, rail retarders or winch retarders are used or in some plants a block of wood under the car wheels is used.

Locomotives of various kinds of motive power are used to switch and spot cars in many plants and for the larger capacity plants are practically a necessity. One utility company is using a remote-controlled electric locomotive, centralizing the control of moving, spotting and emptying the cars at the car dumper. This arrangement is reported to be economical and satisfactory. The car unloader and also the accelerator previously mentioned can move and spot cars by lowering the unloading spuds or screws into the car and operating the overhead traveling trolley, which is a decided advantage for this type of equipment.

Coal Weighing and Sampling

The weighing of coal going into the plant is general but not universal. Weighing of coal to individual boilers is finding less favor than formerly. There is a great variation in the methods of weighing coal and the location of the scales in central-station practice. In some plants the entire car dumper is on scales, and in others simple track scales are used to weigh the coal into the plant and to check the individual car weights, although it is doubtful whether the latter use can be economically justified. Automatic scales are installed at some transition point in the coal-handling system in many plants, while others use weightometers which weigh the coal as it is conveyed by the belt. Coal scales are usually checked frequently and their accuracy is generally conceded to be high.

Obtaining accurate coal samples is a major problem that has not been generally satisfactorily solved. Much attention has been paid to procuring a representative sample and many ingenious and sometimes complicated devices have been used to obtain a sample over the entire width of the conveyor belt. Since the principal variable in the daily coal supply is the moisture content which may change rapidly on exposure of the sample to the air, it would appear that as much or more attention should be paid to the method of caring for the sample as it is being taken and handled up to the time the moisture determination is made, as is paid to complex methods of getting what are thought to be representative samples.

An Aid to Transacting Business with the Government

The Department of Commerce has established a Service and Information Office to steer those manufacturers or contractors who are anxious to do business with the Government but who may lack the specific information on how to proceed. The unit is located in Room 1060, Department of Commerce Building, Washington, D. C., and its function is to inform inquirers whom they should contact and exactly how to do so. It is staffed with men who have had long service with the government and are familiar with the purchase system of each federal department.

Because of the present congestion and confusion in Washington those desiring to transact business with the Government are urged not to come to Washington until they have first communicated with the Service and Information Office and ascertained the proper procedure. When desired, this office will arrange for business men to see the particular official with whom contact should be made. In this way it is felt that business representatives will be able to get in and out of Washington with a minimum of time, effort and expense and return home with a clear understanding of the Government's needs and the necessary procedure in helping to supply them.

Furthermore, firms are urged not to employ outsiders on a commission or other basis. In fact, the War and Navy Departments, as well as the Office of Production Management, have repeatedly warned against the employment of "lobbyists" in efforts to obtain contracts.

It is pointed out that much of the Army purchasing has been decentralized and that actually a very small percentage of the Army supplies is purchased in Washington. On the other hand, the Bureau of Supplies and Accounts purchases a major portion of Navy supplies, aside from contracting for ships, and the Procurement Office of the Treasury Department is the centralized purchasing agency for all departments except the Army and Navy.

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A GRAPHICAL CHECK for FLUE-GAS ANALYSES

By ALAN RUCH
Combustion Engineering Company, Inc.

Construction and use of the Ostwald Chart are explained and typical applications are included for bituminous coal, producer gas and blast-furnace gas.

POWER plant operating and test engineers are all familiar with the use of flue-gas analyses as an indication of combustion conditions in boiler furnaces. Such analyses are also needed to compute flue-gas weights in heat balance tests. Furthermore, the orsat is in daily use in most plants for checking instruments and operating conditions.

As a rule, in plants burning bituminous coal or oil analysis is ordinarily made for CO_2 only. In these plants observations of the furnace and stack are usually sufficient to indicate incomplete combustion, and complete flue-gas analysis is seldom necessary. In plants burning anthracite, coke breeze or gas complete analyses of the flue gas is desirable, even for routine checks of operating instruments. Furnace and stack observations do not disclose incomplete combustion as the flue gases can contain considerable CO with no visible smoke.

The solution used for absorption of CO_2 is stable and can be stored indefinitely or used for long periods with no deterioration. However, those used to absorb oxygen and CO deteriorate rapidly in contact with air or light and should not be stored for long periods. There is always a question in the mind of anyone making complete flue-gas analyses as to whether the pyrogallic and cuprous chloride solutions are all right and if the results are accurate. Also, doubt may exist when the tabulation of gas analysis is made and studied, as for instance: Why did the O_2 vary so much when the CO_2 remained fairly constant; or why did the analyses show CO when the CO_2 was low; or how was it possible to obtain such high CO_2 with no traces of CO?

A rather simple graphical solution to this problem is available but it is little known among power plant operators. A German chemist by the name of Ostwald devised a method of constructing charts representing the relationship between various factors in the products of combustion of hydrocarbons which was published in 1920. Professor Trinks reviewed the highlights of Ostwald's work in an article published in *Blast Furnace and Steel Plant* in January 1922, and mentions the charts in his book on industrial furnaces, published in 1925.

The beauty of the Ostwald Chart is that in its essential details it can be constructed from memory with minimum calculations. It also covers incomplete combustion, thus making it possible to check flue-gas analyses. The only part of the Ostwald Chart requiring laborious calculation are the lines of constant excess air. This article, however, proposes use of the charts as a running check on gas analyses without requiring the lines of constant excess air. The method of construction of the charts given herein is a short cut to the calculations of Ostwald.

The fuel in most power plants does not vary appreciably and usually the ultimate CO_2 is known by the test department and the operators. Remembering the ultimate CO_2 and that air contains approximately 21 per cent O_2 is all that is needed for the first step.

A horizontal base line is drawn and marked off into 21 equal divisions representing per cent O_2 by volume. A vertical line is drawn through the zero point with scale divisions to represent per cent CO_2 and the ultimate CO_2 is located on it; see Fig. 1. A straight line is drawn connecting the ultimate CO_2 point and the 21 per cent O_2 point which is the complete combustion line. On this line will fall the points representing any possible combination of CO_2 and O_2 in the analysis of the flue gases for complete combustion of the particular fuel.

If such a chart is clipped to the orsat case or to the data sheet, each analysis as it is completed can be plotted on the chart for a check. If the plotted points do not fall on the complete combustion line the cause can be investigated immediately. Points above the complete combustion line represent theoretically impossible analyses. Points below the complete combustion line show that CO is present or, if it is not, that some error has been made in the analysis.

Additon of the lines of constant CO are necessary to check points falling below the complete combustion line. If the fuel contains little or no CO_2 as is the case in solid and liquid fuels, and most natural gas or coke-oven gas, the calculation is not difficult.

Assume the fuel is coal that will give an ultimate CO_2 of 18.6 per cent. The analysis by volume of the flue gases resulting from theoretical combustion would be 18.6 per cent CO_2 and 81.4 per cent nitrogen. Assume further that only enough air is supplied to burn the carbon to CO and to burn the hydrogen to H_2O. The gases re-

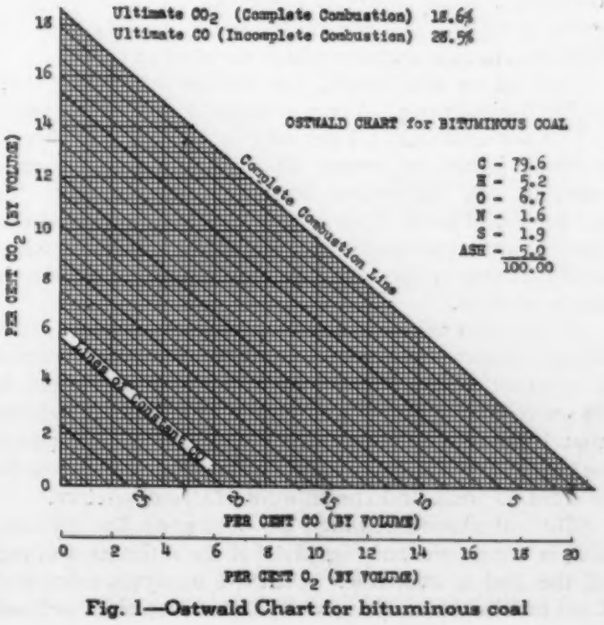


Fig. 1—Ostwald Chart for bituminous coal

sulting from such combustion would contain a volume of CO equaling the volume of CO_2 which would have resulted from complete combustion. But to burn the carbon to CO would require only half the oxygen that would be necessary to burn the carbon to CO_2. Since only half the oxygen is required the volume of N_2 in the flue gases would be reduced by a corresponding amount.

Now write the analysis of the dry products of perfect combustion thus:

$$\left.\begin{matrix}CO_2\text{—}18.6 \text{ per cent}\\ N_2\text{—}81.4 \text{ per cent}\end{matrix}\right\} = \left\{\begin{matrix}CO_2,\ 18.6 \text{ cu ft}\\ N_2,\ 81.4 \text{ cu ft}\end{matrix}\right.$$

If only enough air were used to burn the carbon to CO the actual volume of CO in cubic feet would remain 18.6 cu ft. The volume of oxygen required would have been one-half of that required for complete combustion and therefore would be 9.3 cu ft. The volume of nitrogen in the air accompanying the oxygen would be $\frac{79}{21} \times 9.3$ cu ft or approximately 35 cu ft. This volume subtracted from the 81.4 cu ft gives 46.4 as the volume of nitrogen in the dry products of incomplete combustion. The total dry products of incomplete combustion then are

$$\begin{matrix}CO\text{—}18.6 \text{ cu ft}\\ N_2\text{—}46.4 \text{ cu ft}\\ \hline 65.0\end{matrix}$$

and the per cent by volume is

$$\begin{matrix}CO\text{—}\ 28.6 \text{ per cent}\\ N_2\text{—}\ 71.4 \text{ per cent}\\ \hline 100.0 \text{ per cent}\end{matrix}$$

On the chart 28.6 per cent CO is at the point representing zero CO_2 and zero O_2. Through this point draw a line perpendicular to the complete combustion line. Divide the line into a suitable scale geometrically and draw lines through these points parallel to the complete combustion line. These are the lines of constant CO, and the chart is complete except for the lines of constant excess air which are not required for the purpose intended herein.

Examination of the chart will show that if an analysis of the flue gas shows CO and fails to fit the chart, an error in analysis is clearly indicated. For example, a common orsat error is the failure to absorb all the O_2 in the pyrogallic solution, the remainder being absorbed in the cuprous chloride solution which shows it as CO.

Assume we are burning the fuel for which the chart in Fig. 1 was drawn. A true analysis of the flue gas might be, 14 per cent CO_2, 5.1 per cent O_2 and no CO, whereas through failure to absorb all the O_2 in the pyrogallic solution, the indications might be 14 per cent CO_2, 4.1 per cent O_2 and 1 per cent CO. It will be noted that this hypothetical analysis does not fit the chart, which indicates that a check should be made to determine the cause of error.

If CO does exist in the flue gases it sometimes is not shown because the cuprous chloride solution is inactive. Consistent analyses then which, for example, might be 14 per cent CO_2, 4.3 per cent O_2 and no CO would indicate that 1 per cent CO is present in the flue gas and should be found by the orsat analysis, or that the pyrogallic solution is weak and the cuprous chloride inactive.

The calculation required to determine the ultimate CO_2 is not particularly involved if the ultimate analyses of the fuel is available. Ultimate analyses calculated from proximate analysis by any of the empirical methods are sufficiently accurate for construction of an Ostwald Chart intended for checking flue-gas analyses.

Complete combustion of one pound of carbon requires approximately 30 cu ft of O_2 and produces 30 cu ft of CO_2 (the volumes are at 32 F and 30 in. Hg).

Complete combustion of one pound of hydrogen requires 89 cu ft of O_2 or one pound of hydrogen plus 8 lb of O_2 = 9 lb H_2O.

The ultimate analysis of the fuel will show carbon, hydrogen, oxygen, nitrogen, sulphur and ash, in per cent by weight. Let the actual weight of the constituents in pounds per pound of fuel be represented by c, h, o, n, s, then the theoretical volume of oxygen, O, required per pound of fuel is $30c + 89\left(h - \frac{o}{8}\right) + 12.8\,n$. The volume of nitrogen, N, per pound of fuel, brought in with the oxygen is $O \times \frac{79}{21}$. The total volume of dry flue gas per pound of fuel is $30c + N + 12.8n$ and the ultimate per cent of CO_2 in the flue gas is $\frac{30c}{30c + N + 12.8n}$. (NOTE: The term $12.8n$ is the nitrogen in the fuel by weight multiplied by 12.8 which is the cubic feet of N_2 per pound at 32 F and 30 in. Hg. In most solid fuels, the nitrogen can be neglected as the actual volume is too small to affect the results appreciably.)

As suggested previously, the ultimate CO representing the incomplete combustion can be derived from the gas analysis representing perfect combustion. The ultimate CO can also be computed as follows:

One pound of carbon with 15 cu ft of oxygen produces 30 cu ft of CO; so the theoretical oxygen in cubic feet for incomplete combustion of one pound of fuel is $15c + 89\left(h - \frac{o}{8}\right)$, and the nitrogen added with O_1 is $\frac{79}{21}O_1$. The total cubic feet of dry flue gas resulting from the incomplete combustion is $30c + 12.8n + N_1$, and the ultimate CO in per cent by volume is $\frac{30c}{30c + 12.8n + N_1}$.

The charts can be constructed for any fuel gas by means of the simple form described for solid fuels providing the fuel gas does not contain CO_2. Fuel gases such as blast furnace gas, producer gas and a few natural gases contain an appreciable quantity of CO_2.

Charts for these gases are slightly different since the flue gases resulting from incomplete combustion will contain CO_2 even when the ultimate CO is reached. The following are the constants and calculations necessary to construct the charts for gaseous fuels:

TABLE 1—COMPLETE COMBUSTION

Gas	Formula	Cu Ft per Cu Ft Combustible			Products of Complete Combustion Cu Ft per Cu Ft		
		O_2	N_2	Air	CO_2	N_2	H_2O
Hydrogen	H_2	0.5	1.882	2.382	...	1.882	1.0
Carbon monoxide	CO	0.5	1.882	2.382	1.0	1.882	...
Carbon dioxide	CO_2	...	...	...	1.0	...	...
Methane	CH_4	2.0	7.528	9.528	1.0	7.528	2.0
Ethane	C_2H_6	3.5	13.175	16.675	2.0	13.175	3.0
Ethylene	C_2H_4	3.0	11.295	14.293	2.0	11.293	2.0
Acetylene	C_2H_2	2.5	9.411	11.911	2.0	9.411	1.0

TABLE 2—INCOMPLETE COMBUSTION; C TO CO AND H_2 TO H_2O

Gas	Formula	Cu Ft per Cu Ft Combustible			Products of Incomplete Combustion		
		O_2	N_2	Air	CO	N_2	H_2O
Carbon monoxide	CO	...	...	...	1.0	...	...
Carbon dioxide	CO_2	...	...	...	...	...	...
Methane	CH_4	1.5	5.646	7.146	1.0	5.646	2.0
Ethane	C_2H_6	2.5	9.410	11.910	2.0	9.410	3.0
Ethylene	C_2H_4	1.5	5.646	7.146	2.0	5.646	2.0
Acetylene	C_2H_2	2.0	7.528	9.528	2.0	7.528	1.0

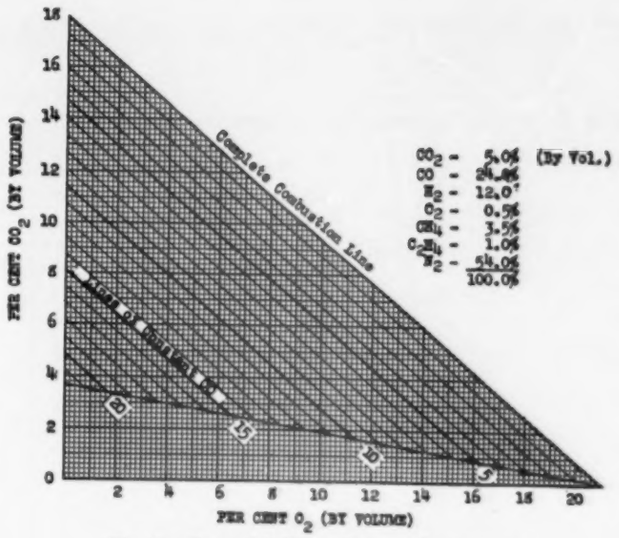


Fig. 2—Ostwald Chart for producer gas

The fuel-gas analysis will show $CO_2 + CO + H_2 + O_2 + CH_4 + C_2H_4 + C_2H_6 + N_2 = 100$ per cent by volume.

The theoretical volume of oxygen for complete combustion of one cubic foot of fuel gas is $O =$

$$\frac{0.5CO + 0.5H_2 + 2CH_4 + 3.5C_2H_6 + 3.0C_2H_4 + 2.5C_2H_2 - O_2}{100}$$

The volume of CO_2 produced per cubic foot of fuel gas is

$$CO_2 = \frac{CO_2 + CO + CH_4 + 2C_2H_6 + 2C_2H_4 + 2C_2H_2}{100}$$

The volume of nitrogen brought into the flue gases with the oxygen for combustion is added to the volume of nitrogen per cu ft of fuel gas, thus:

$$N = \frac{79}{21} O + \frac{N_2}{100}$$

The theoretical CO_2 is: CO_2 (per cent by vol.) $= \frac{CO_2}{CO_2 + N}$

The theoretical volume of oxygen required to burn one cubic foot of fuel gas, all C to CO and H_2 to H_2O, is:

$$O = \frac{0.5H_2 + 1.5CH_4 + 2.5C_2H_6 + 1.5C_2H_4 + 2C_2H_2 - O_2}{100}$$

The volume of nitrogen accompanying the oxygen for incomplete combustion of one cubic foot of fuel gas added to the N_2 in the fuel gas is:

$$N = \frac{79}{21} O + \frac{N_2}{100} \text{ cu ft}$$

The theoretical volume of CO produced by the incomplete combustion of one cubic foot of fuel gas is:

$$CO = \frac{CO + CH_4 + 2C_2H_6 + 2C_2H_4 + 2C_2H_2 \text{ cu ft}}{100}$$

The theoretical volume of CO_2 in the flue gas for one cubic foot of fuel gas is $\frac{CO_2}{100}$; the per cent CO in the dry flue gases is $\frac{CO}{CO + N + CO_2}$; and the per cent CO_2 is $\frac{CO_2}{CO + N + CO_2}$.

In constructing the chart for gas the complete combustion line is drawn as previously described. The point representing ultimate CO, however, does not lie at zero CO_2 but at the point on the CO_2 scale representing per cent CO_2. Draw a line through this point perpendicular to the complete combustion line and divide geometrically into a suitable scale. The lines of constant CO are drawn parallel to the complete combustion line terminating at a line drawn through the point representing CO and CO_2 and 21 per cent O_2.

Constructing Chart for Producer Gas

The following calculation and construction of a chart for producer gas will illustrate the method. Assume the analysis of the fuel gas to be:

	Per cent
CO_2	5.0
CO	24.0
H_2	12.0
O_2	0.5
CH_4	3.5
C_2H_4	1.0
N_2	54.0
	100.0

Substituting these values in the equations given, the oxygen required for complete combustion is:

$$O = \frac{(0.5 \times 12) + (0.5 \times 6.0) + (2.0 \times 3.5) + (3.0 \times 1.0) - 0.5}{100}$$

$$O = \frac{27.5}{100} = 0.275 \text{ cu ft per cu ft fuel gas}$$

The theoretical volume of CO_2 in the flue gas:

$$CO_2 = \frac{5.0 + 24.0 + 3.5 + (2 \times 1)}{100}$$

$$CO_2 = \frac{34.5}{100} = 0.345 \text{ cu ft per cu ft fuel gas,}$$

and the volume of nitrogen in the flue gas is:

$$N = \frac{79}{21} \times 0.275 + \frac{54}{100}$$

$$N = 1.575 \text{ cu ft per cu ft fuel gas}$$

The per cent CO_2 in the dry flue gases then is:

$$CO_2 \text{ (per cent by volume)} = \frac{0.345}{0.345 + 1.575} = 17.95 \text{ per cent}$$

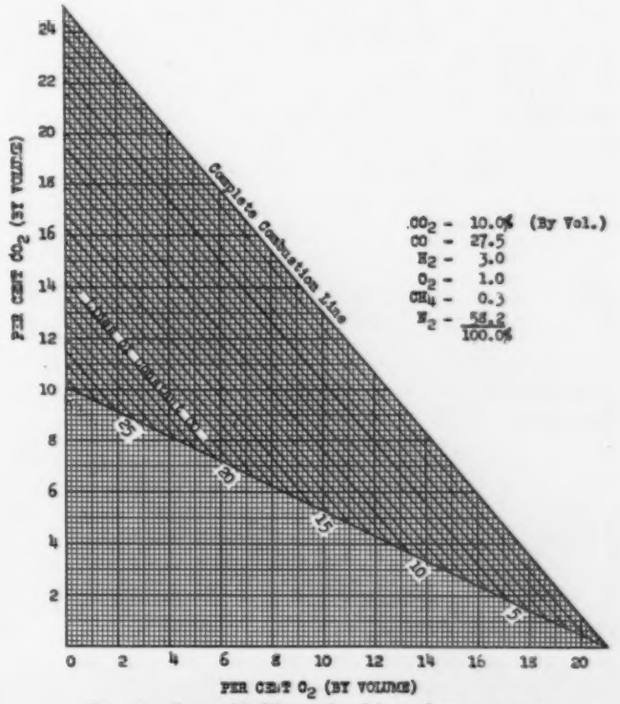


Fig. 3—Ostwald Chart for blast-furnace gas

On the vertical scale (see Fig. 2) locate the point for 17.95 per cent CO_2 and draw the complete combustion line.

For incomplete combustion, substituting in the equations the oxygen required is:

$$O = \frac{(0.5 \times 12) + (1.5 \times 3.5) + (1.5 \times 1.0) - 0.5}{100}$$

$$O = 0.1225 \text{ cu ft per cu ft fuel gas}$$

The maximum volume of CO in the flue gas:

$$CO = \frac{24.0 + (1 \times 3.5) + \times 2 \times 1.0)}{100}$$

$$CO = 0.295 \text{ cu ft per cu ft fuel gas}$$

The volume of CO_2 in the flue gas:

$$CO_2 = \frac{5.0}{100} = 0.05 \text{ cu ft per cu ft fuel gas}$$

and the volume of nitrogen in the flue gases:

$$N = \frac{79}{21} \times 0.1225 + \frac{54.0}{100}$$

$$N = 1.011 \text{ cu ft per cu ft fuel gas}$$

The percentages by volume are:

$$CO = \frac{0.295}{0.295 + 0.05 + 1.011} = 21.8 \text{ per cent by volume}$$

and

$$CO_2 = \frac{0.05}{0.295 + 0.05 + 1.011} = 3.69 \text{ per cent by volume}$$

Locate the ultimate CO point at 3.69 per cent on the CO_2 scale and draw the line connecting it to the 21 per cent O_2 point. Draw the perpendicular to the complete combustion line through 3.69 per cent on the CO_2 scale, divide into 21.8 divisions geometrically and draw in the constant CO lines.

Chart for Blast-Furnace Gas

Another example of a fuel gas containing a high percentage of CO_2 is found in blast-furnace gas. It is unique in that the combustible portion is chiefly CO with a very small percentage of H_2 and even smaller percentages of hydrocarbons. Use of the Ostwald chart is quite helpful in checking orsat analyses of the flue gases from blast-furnace gas. The method of construction is identical to that given for producer gas but an example may prove of interest.

A blast-furnace gas analysis is given as:

CO_2 —	10.0
CO —	27.5
H_2 —	3.0
O_2 —	1.0
CH_4 —	0.3
N_2 —	58.2
	100.0

Substituting these in the equations given, the oxygen required for theoretical combustion is:

$$O = \frac{(0.5 \times 27.5) + (0.5 \times 3.0) + (2.0 \times 0.3) - 1.00}{100}$$

$$O = 0.1485 \text{ cu ft per cu ft fuel gas}$$

The total volume of nitrogen in the fuel gas is:

$$N = \frac{79}{21} \times 0.1485 + \frac{58.2}{100} = 1.141 \text{ cu ft per cu ft fuel gas}$$

The volume of CO_2 is:

$$CO_2 = \frac{(1.0 \times 10.0) + (1.0 \times 27.5) + (1.0 \times 0.3)}{100}$$

$$CO_2 = 0.378 \text{ cu ft per cu ft fuel gas}$$

and the percentage by volume is:

$$CO_2 = \frac{0.378}{0.378 + 1.141} = 24.9 \text{ per cent by volume}$$

For incomplete combustion the oxygen required is:

$$O = \frac{(0.5 \times 3.0) + (1.5 \times 0.3) - 1.00}{100}$$

$$O = 0.0095 \text{ cu ft per cu ft fuel gas}$$

The total volume of nitrogen in the flue gas is:

$$N = \frac{79}{21} \times 0.0095 + \frac{58.2}{100} = 0.6195 \text{ cu ft per cu ft fuel gas}$$

and the theoretical volume of CO will be

$$CO = \frac{(1 \times 27.5) + (1 \times 0.3)}{100} = 0.278 \text{ cu ft per cu ft fuel gas}$$

The volume of CO_2 in the flue gas is:

$$CO_2 = \frac{10.0}{100} = 0.10 \text{ cu ft per cu ft fuel gas}$$

and the percentages are:

$$CO = \frac{0.278}{0.278 + 0.10 + 0.6195} = 27.9 \text{ per cent by volume}$$

$$CO_2 = \frac{0.10}{0.278 + 0.10 + 0.6195} = 10.1 \text{ per cent by volume}$$

The chart is then constructed as shown by Fig. 3.

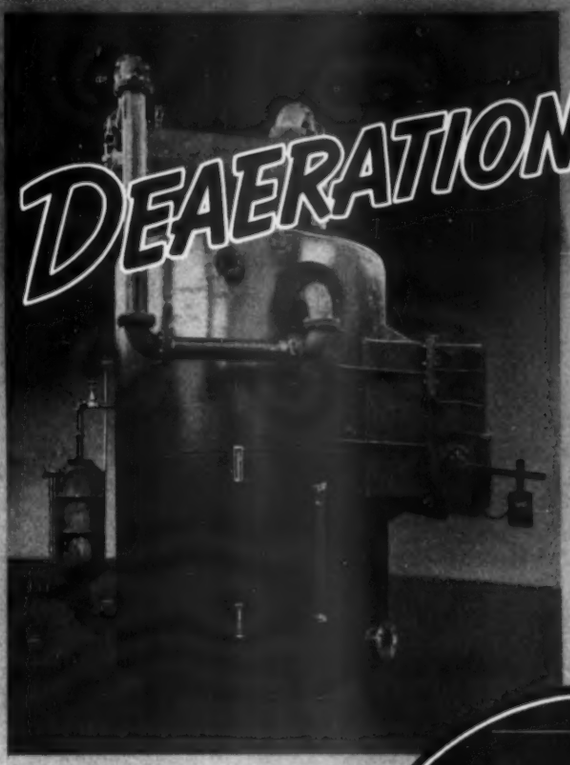
Trial calculation of the Ostwald Chart for various types of coal will show that a fairly wide range of coal can be covered with a single chart without enough difference to exceed the possible limit of accuracy of an orsat analysis. It will also be found that carbon loss does not affect the accuracy of the chart unless it reaches such a proportion that the carbon loss is plainly indicated by the appearance of the fly ash and ash pit refuse. Five per cent carbon loss for instance does not change the complete combustion line enough to make a readable difference.

The Ostwald Charts are based on the assumption that all hydrogen in the fuel is completely burned, a condition which in practice may not be true for extreme cases. It is a rare case that deficiency of the air supply to a boiler furnace is so bad that unburned hydrocarbons exist in the flue gases without producing smoke. However, when the charts are used as proposed in this article as a check on orsat analyses, unburned hydrocarbon would be indicated by failure of the flue gas analyses to fit the chart in spite of all precautions taken to insure accurate analysis for CO_2, O_2 and CO.

Changes in Elliott Organization

The Elliott Company, Jeannette, Pa., has announced a number of changes in its organization personnel. **L. M. Fornerook** is now vice president in charge of manufacturing operations of the company's three plants; **V. H. Peterson** has been advanced from general sales manager to vice president in charge of district offices, sales and advertising; **L. E. Nohl** has been elected a vice president in charge of financial and accounting functions; **W. A. Elliott** has been made vice president in charge of marketing research and purchasing; **M. A. King** has been made manager of engineering; **J. R. McDermet** continues as chief engineer; and **W. A. Yost** steps up to manager of the turbine sales department.

DEAERATION by ATOMIZATION

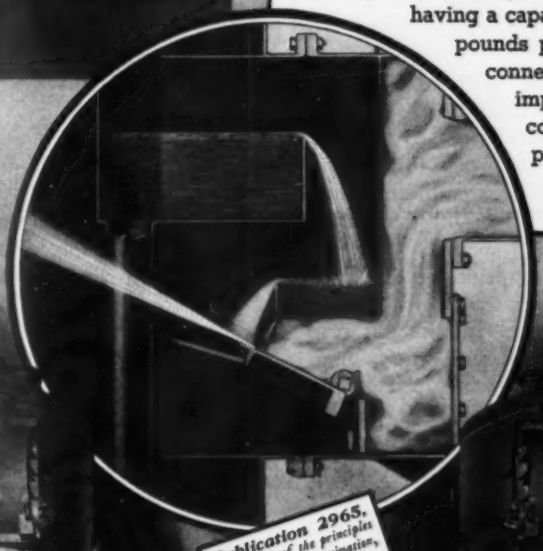


THE Cochrane atomizing type of deaerator is particularly well adapted to the handling of encrusting and corrosive water supplies. It is standard equipment on all Cochrane Hot Process Water Softeners where it is necessary to deaerate the settled and unfiltered water supply.

It has been very successful in the independent deaeration of corrosive water supplies such as might result from acid treatment of zeolite effluents. These waters, high in carbon dioxide and low in pH value, are corrosive to ordinary types of heaters; however, experience has indicated that with the Cochrane atomizing type unit there is no corrosion of the internal parts. Deaeration is complete, reducing the oxygen to zero, and units having a capacity of well over 1,000,000 pounds per hour are in service in connection with some of the most important industrials in the country operating high pressure boilers.

(Above) Vertical Cylindrical Atomizing Deaerator of 400,000 lb./hr. capacity.

(Circle) Sectional View of Atomizing Chamber, showing action of Atomizing Valves.



(Below) Two Vertical Cylindrical Atomizing Deaerators, each of 500,000 lb./hr. capacity, mounted on Horizontal Rolled Plate Storage Tanks.

Publication 2965, a discussion of the principles of deaeration by atomization, will be mailed on request.

Cochrane Corporation

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WATER SOFTENERS • DEAERATING HEATERS • DEAERATORS • BLOW-OFF EQUIPMENT • VALVES • FLOW METERS

WHAT HAS BEEN HAPPENING IN LOAD AND CAPACITY?

By **COLONEL H. S. BENNION**, New President and Managing Director, Edison Electric Institute

Excerpts from an address before the Annual Convention of the Edison Electric Institute, Buffalo, N. Y., June 5, in which the author reviews the problem of the utilities in meeting the uncertain power demands created by the rapidly expanding defense program, cites figures on new capacity under construction and on order, and points out various factors and expedients that can alleviate a power shortage.

THE statistician of the Office of Production Management recently estimated that production was increasing so swiftly that the federal expenditures for both defense and non-defense purposes, which were $1,300,000,000 in April 1941, would reach 2 billion a month, or 24 billion a year by July. His yearly estimate was $5,000,000,000 greater than the estimate that the Secretary of the Treasury made a week earlier; but in either case the expansion indicated is enormous.

This huge government spending, without the depressing influences of participation in actual war, and coupled with purchases by foreign governments, has created boom times with their usual stimulation of industry and business superimposing their power demands on top of the demand pertaining strictly to rearmament operations.

Fig. 1 shows the domestic service price history, during more than a quarter century, contrasted with the upward climb of three important cost elements entering into it which are beyond, or largely beyond, the control of utility management, namely, taxes, fuel prices and hourly wage rates. The cost of domestic service is down 56 per cent, fuel is up 75 per cent, hourly wages up 215 per cent and taxes up 268 per cent since 1913. The estimated yearly total output of electricity by both the power industry and isolated industrial plants during this period is indicated in Fig. 2. It will be noted that the expansion has taken place in the utility field.

Fig. 3 shows the total electric output in the United States over the past twenty years compared with that for Japan, Great Britain and Germany to the extent that information is available.

Fig. 4 shows the expansion of power from 1913 to 1940, contrasted with the growth of population, of industrial production and of transportation. Electric power expansion is still well in the vanguard.

Fig. 5 shows the total installed capacity of all generating plants contributing to the public supply and the sum of the noncoincident peak demands over the same period. It will be observed that 1938 was a year of reduced industrial capacity. The outbreak of war in Europe in 1939 caused a jump in the peak demand amounting for the entire country to about 3,600,000 kw. Greater prosperity and the incidence of additional war loads in 1940 increased the sum of noncoincident peak demands another 2,200,000 kw. Estimates of individual utility companies made in February indicate an increase of another $2^3/_4$ million kilowatts in the sum of noncoincident peak demands by December 1941.

On this chart is also shown the estimated additions to total installed capacity contributing to the public power supply as indicated by reports and announcements of electric utilities, municipal and district plants and

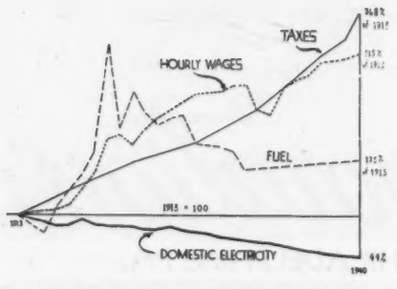

Fig. 1—Domestic rates for electricity compared with fuel costs, wages and taxes from 1913 to 1940

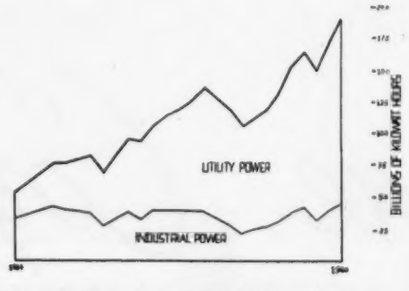

Fig. 2—Total output of all prime movers, 1914 to 1940

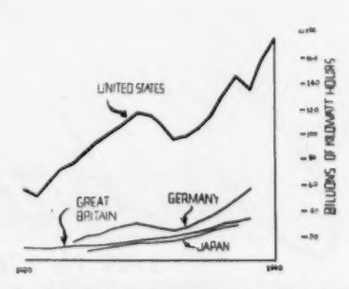

Fig. 3—Electric output in United States compared with Great Britain, Germany and Japan

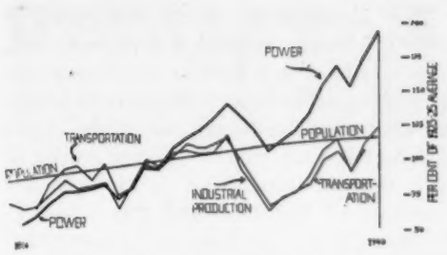

Fig. 4—Principal economic indices, 1914 to 1940

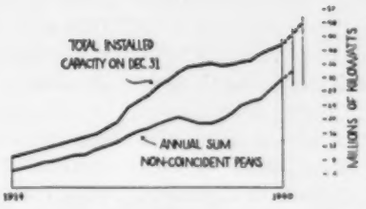

Fig. 5—Growth of generating capacity and noncoincident peak loads, 1914 to 1940

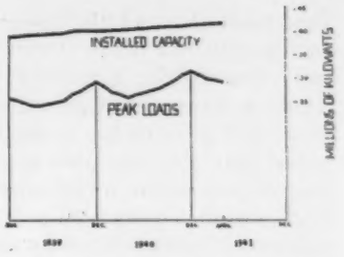

Fig. 6—Recent peak loads

Federal Government projects. In addition to the foregoing, industrial plants themselves will install more than 600,000 kw of industrial steam capacity in 1941. The 1941 installations by the electric utilities themselves amount to approximately 2,100,000 kw and in 1942 approximately 2,500,000 kw. Already, announcement of capacity to be installed in 1943 amounts to 1,045,000 kw. The bulk of this capacity is steam power to be located in the heavy industrial areas east of the Mississippi and north of the Ohio and the Potomac.

Fig. 6 shows the trend of installed capacity and of peak loads during recent months. This picture is reassuring.

Fig. 7 indicates the behavior of load factor during the past two years. There has been some little improvement. This is more pronounced since the first of the year. It indicates that factories are working more shifts, but the improvement is short of expectations.

These charts are useful merely to give a general picture of the load and capacity situation. They indicate the order of magnitude of the various factors and give a reasonably good measure of the trend of developments. Beyond this they have little value. It is not possible by statistics to give a true measure of the engineering and operating factors pertaining to the load and ability to supply it in any particular territory or group of areas. In the first place, to collect and compile statistical data, it is necessary to set up assumed limits and definitions which fit only roughly any one area for any length of time.

Another engineering relationship that is too complicated for statistics is the capacity and output to be expected from hydro plants used alone or, more particularly, when used in conjunction with steam stations. In order to make a statistical tabulation of these factors, limiting conditions must be assumed. This usually means that capacity is put down at the figure that would prevail for a two- to four-month period during a record dry year. Such a time seems to be developing in two or more areas now. In practice when drought conditions are encountered, however, other reserves, interconnections and special methods of operation or rearrangement of loads are always worked out to meet the situation. There is a flexibility in actual operation which cannot be reflected in statistical tabulations, and, while the effects of drought on power supply loom large at the time, in retrospect the net effect on the year's power output shows up relatively small.

Next, there is the question of reserves and the amount of spare capacity which should be carried. The necessary reserve under normal conditions hinges upon many factors—for instance, upon the size of the largest generator which might be out of service on a given system at any one time, whether due to breakdown or overhauling or repairs; or upon the need to run certain units to get a particular quality of local service; or upon conditions in neighboring systems, such as the status of their reservoirs, of their fuel supplies; or upon the characteristics of loads being served at a particular time of the day, week or season. Here again rule of thumb formulas have some usefulness. They afford broad and general guides for particular and general purposes, but that is as far as they can go. The element of skill, of experience, of judgment, controls. Power plants and transmission systems of the industry are run by competent, loyal, experienced, skilled forces of operators, whose ability to turn out the power has not failed in the hour of need. The experience and resources of the organization operating a power system may be a bigger factor in the resulting service from it than the extent and condition of the reserves. Reports from the bombed areas of England bear out this observation.

Further, in trying to size up aggregate available electric capacity in any area, there is still another big factor which makes even the best statistics on capacity of limited value unless skilfully interpreted. This factor arises out of the enormous extent to which interconnections exist between power stations. Unless the entire country be taken as a single area, any attempt to determine capacity by regions will necessarily omit interregional capacity possibilities. Once more the answer is that judgment and experience determine what capacity can be secured in a particular area, especially so in emergencies.

Utility Industry's Responsibility

From the standpoint of cost and convenience, electric utilities have a monopoly of the power supply for the domestic and small commercial business and have assumed a continuing responsibility to supply such loads. They have won a large share of the business of large commercial and large industrial concerns, but because they have only a part of that business it follows that they have only a partial responsibility for supplying that class of load. Analysis of the sources of power made use of by different classes of industry shows that electric utilities have about 60 per cent of the responsibility for supplying power to the great steel industry and less than half the responsibility for supplying power to the chemical industry. It happens that the sharpest rises in power demand produced by the war effort have been in this latter industry.

In certain sections of the country large Federal power projects constructed in recent years have assumed an

important share of the responsibility for supplying the increased power needs of those regions. This is particularly true in the Tennessee Valley, to some extent in Texas and southern California and in the Pacific Northwest, and it is to the Tennessee and Columbia Valley areas that the big new aluminum power loads have largely gravitated. The uncertainties arising from the intrusion of Federal projects into these areas in fact rendered it most difficult for electric utilities in adjoining areas to make advance provision of additional generating capacity with which to supply the greatly increased loads which have sprung up as a result directly and indirectly of the rearmament program.

Fig. 8 shows the total mechanical power used by factories in America. The nonmechanical uses for the production of aluminum, chemicals, electric heat treating, etc., are not included. It will be observed that in 1914 the responsibility of the electric light and power industry was only 17 per cent of the total; in 1919 it was 32 per cent of the total, and in 1939 it had risen to 58 per cent.

Electric generating capacity added by industrial plants themselves in 1940 was approximately 450,000 kw and in 1941 they will add more than 675,000 kw of steam capacity. The addition for 1941 is approximately 35 per cent of the amount to be added by electric

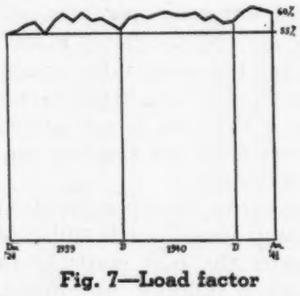

Fig. 7—Load factor

utilities during the same period. Up to May 15, about 75,000 kw were scheduled to be installed by industrial plants in 1942.

Future Adequacy

The large installation program for 1941 and 1942 is generally considered sufficient to assure adequate power capacity to meet increased demands between now and the end of 1942. Of course, there will be some spots where the munitions loads will tax the power supply facilities. The weather man will have something to say about this in water power areas, and he has not been acting favorably so far this year in several sections of the country.

Adequacy in 1943 and succeeding years will, of course, depend on a number of factors. On the one hand, it will depend on still further expansion of the armament program and the speed maintained in actual production; and further expansion in turn is largely based upon the foreign policy this country may decide upon. On the other hand, to balance or offset the increased power demand by reason of further program expansion there will be the additional generating capacity installed subsequent to 1942 to meet the estimated growth of demand. Already the private utilities have announced plans for 827,000 kw in 1943 and municipal and government power projects bring this total to 1,045,000 kw. The installation of 670,000 kw of generating capacity is already scheduled for 1944. On this same side of the balance are factors which will exercise some compensating reduction on the overall power demand. These factors are the taking out of the ranks of industry of additional manpower to fill the ranks of the armed forces; the curtailment of production for civilian supply because of taxation and other factors which will reduce buying power, and because of priorities and other controls on such supply; then there may be other causes of reduced or delayed production such as strikes, the lack of ocean shipping facilities, etc. Furthermore, the working of munitions plants more days in the week and longer hours in the day will serve to hold down the growth of demand. There has already been some improvement in this regard in recent months. Another helpful factor can be the shifting of loads, particularly loads of heavy demand characteristics, to off-peak hours of the day and week.

Some of the growth of demand that already has been experienced is nonrecurrent. This is true of the starting up and speeding up of operations of factories which in the summer of 1939 were idle or were running at part capacity. Much of the construction program is now completed or shortly will be so, and the power consumption for that construction or for the producing, fabricating and hauling of those construction materials is over with. The expansion history of the past twelve months, however, shows the importance of watching closely the course of our foreign policy and of making some allowance for the unexpected. Business nowadays is determined by government plans. The usual business criteria are submerged.

Forehanded Steps Utilities Can Take

While statements of those directing the huge armament program would indicate that the peak demand will come before the end of 1942, nevertheless we must recall how greatly the program has been expanded in the past several months and therefore should keep an alert watch for evidences of any further expansion and plan construction accordingly. As pointed out before, business now is mostly determined by government plans. In addition to keeping this sharp lookout, it is suggested that the following four steps, which many companies are following, can profitably be taken by all.

1. Study carefully industrial loads and means to shift them around the clock so as to produce improvement in load factor. A number of companies working at this have accomplished remarkable load factor im-

(*Continued on page 54*)

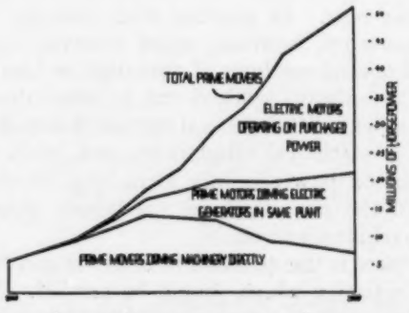

Fig. 8—Growth in industrial electrification in the United States

UNQUESTIONED SUPERIORITY

FIRSTS

UNDER ARM SUPPORTS ELIMINATE 95% OF ELEMENT WARPAGE

BUILT-IN, ADJUSTABLE ORIFICE GIVES EXACT PRESSURE AT EACH HEAD

ADJUSTABLE STOPS FOR PROPER BLOWING ARC

POSITIVE CONTROL FOR PROPER CLEANING POSITION

EXCLUSIVE COMPRESSION ALLOY BEARINGS FOR HIGH TEMPERATURE

FIRSTS

ELEMENT UNION FOR EASE OF ELEMENT REPLACEMENT WITHOUT DANGER OF BREAKAGE OF HEAD PARTS

NO VALVE PACKING. VULCAN CONSTRUCTION OF STEAM ACTUATED VALVE ELIMINATES IT

NO VA STEMS TO REPLA ECAUSE OF PRESSU ENDING OR B R K A G E

VULCAN
SOOT BLOWERS

IN almost every industry there is one outstanding example of the highest quality of product in that industry. The manufacturer of that product is not necessarily the largest in size or in volume of output. Because high quality means better materials, more careful, more accurate work by more skilled workmen, production is limited by the demand for the higher quality product.

In the field of soot blowers Vulcan occupies that enviable position. This statement may be verified by a check-up of the many Vulcan installations in the boiler plants of industrials, utilities and merchant and navy ships. Vulcan superiority is outstanding.

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SAMPLING of Steam and Boiler Water*

By A. R. BELYEA[1]
and A. H. MOODY[2]

The principles of representative sampling as applied to the sampling of steam and boiler water are reviewed. Sampling lines, cooling coils and containers must preserve the integrity of the sample by suitable choice of materials of construction. Metals and alloys for this purpose are discussed from the standpoint of corrosion resistance in the presence of the chemical impurities in the steam, boiler waters and cooling water.

IN THE sampling of steam and boiler water, obtaining a properly representative sample implies:

1. Proper choice of sampling locations.
2. Withdrawal of sample at the chosen locations in a proper manner.
3. Bringing the sample, without contamination or loss of integrity, from elevated temperature and pressure to atmospheric pressure and a temperature suitable for analysis.
4. Collecting a sufficient volume of sample for ensuing analytical determinations.
5. Collecting samples with sufficient frequency to gage accurately changing conditions within the container from which the sample is taken.
6. Storing the sample prior to analysis in such a manner as will safeguard against change in the particular properties to be determined.

Choice of Sampling Locations

Selection of sampling points should not be undertaken without a thorough knowledge of the operation and functions of the equipment from which the sample is to be taken. In modern boilers of high capacity and high pressure the rapid throughput of feedwater and the complicated circulation during operation make it advisable to conduct a survey of the boiler by taking samples at many points in order to determine the proper point or points to obtain a sample that will furnish the desired information.

For example, a perforated pipe inserted lengthwise in a boiler drum or collecting header for collecting an "average" sample will often draw steam preferentially from the perforations nearest the header or drum shell. When sampling steam in motion, as in mains, it is necessary to extract the sample at the same linear velocity as the steam passing the sampling point. It is preferable to insert the sampling nozzle into a vertical straight run of pipe some distance from any bend or fitting in order to minimize the effects of possible stratification. If the stream to be sampled is not uniform due to stratification, more than one sampling point may be advisable.

Obtaining a Representative Sample of Boiler Water

As in the case of steam sampling, the withdrawal of the boiler water sample from the selected point or points must be performed in such a manner as to insure the same ratio of solids to liquid in the sample as in the fluid being sampled. Sufficient sample water must be discarded or discharged overboard at the start of collection so that any stagnant water in the lines or at the point of sampling is disposed of prior to sample collection. This is especially necessary if appreciable quantities of suspended or insoluble solids are present which may settle out at or near the sampling point. It is also advisable to do likewise in the case of new sampling nozzles and lines, as many of the commonly used metals develop protective interior surface coatings on initial contact with boiler water, and this reaction should be completed prior to actual sample collection where extreme accuracy is required.

A metal filter may be inserted at the point of sampling if it is desired to remove the insoluble solids from the boiler water before cooling. This may be necessary to avoid reaction between insoluble solids and the boiler water while the sample is being cooled and collected or to avoid atmospheric contamination during laboratory filtration by ordinary methods.

The choice of materials for construction of sampling lines must take into account the pressures and temperatures involved, to avoid structural failure. Except for strongly acid or alkaline waters, chemical considerations are not so pronounced, since in most instances time of contact of the sample and sampling line can be minimized through judicial choice of rate of flow and diameter of line. On the other hand, the sampling lines will operate generally at a continuously higher temperature than those parts of the sampling equipment in contact with cooling water, so that any progressive chemical reaction will be more rapid due to the higher temperature. As a generalization, the use of the same material for sampling lines as is used for the container from which the sample is being withdrawn is permissible, provided contact times are short.

Cooling Coils

In bringing the sample to pressure and temperature conditions suitable for storage and analysis, the prevention of contamination is of major importance where conductivity measurements are to follow, as relatively small concentrations of dissolved gases or metallic ions

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* Excerpts from a paper presented at a Symposium on Determination of Steam Purity during the recent Annual Meeting of the A.S.T.M. at Chicago.

[1] Chemical Engineer and [2] Chemist-in-Charge, respectively, Consolidated Edison Company of New York, Inc., New York, N. Y.

may introduce appreciable errors in the determination. Hence the corrosion resistance of metals and alloys suitable for construction of sampling lines and cooling coils is a major consideration in modern sampling practice.

The cooling coil must handle the quantity of sample decided to be necessary; reduce the temperature of the sample, generally to room temperature; and discharge the sample at a lower pressure, usually atmospheric. The amount of heat-absorbing surface required will vary with the temperature and velocity of the sample water or condensate and the temperature and rate of flow of the cooling water, as well as with the design of the coil.

In considering corrosion resistance for cooling coil service, not only the nature of the condensed steam or boiler water must be considered but the nature of the cooling water as well; the latter may be the controlling factor governing the selection of materials. A common design of cooling coil consists of two tubes, one within the other. The cooling water enters the outer tube at the bottom and leaves at the top, completely surrounding the inner tube at all points. The hot test sample enters the top of the inner tube and leaves at the bottom. While there are slight modifications of the foregoing design between coils supplied by manufacturers, such as the use of tube and shell instead of two tubes, the principle of counter-current flow is usually employed.

In considering metals for the fabrication of cooling coils, a wide variety of useful corrosion-resistant metals and alloys is available for choice. The problem is to select that which best meets the particular set of conditions confronting the user with regard to corrosion resistance, physical properties and cost.

Suitability of Various Metals

The following paragraphs provide a very general discussion of the relation between the sampling of steam and boiler water and the corrosion-resistant properties of iron and steel, including stainless steels; copper, brasses, and bronzes; nickel and monel; aluminum; tin and rare metals.

IRON AND STEEL. Iron and steel are commonly used in the sampling of steam and boiler water where pressures and temperatures involved are low, limits of boiler water constituents are wide and accuracy of tests is nominal. As greater demands are placed on sampling in the higher pressure and temperature range, iron contamination cannot be permitted, and ferrous alloys and non-ferrous alloys and metals are utilized.

STAINLESS STEELS. Stainless steels find wide application where corrosion resistance is a requisite. It is generally agreed that this freedom from corrosion is due to the formation of a protective surface film, a product of reaction between the metal and a corroding medium. Both nickel and chromium, the major alloying elements with iron to produce stainless steels, have the same property of developing surface passivity. Increasing corrosion resistance is obtained in the case of chromium steels by increasing the chromium content.

Stainless steels find successful application in cooling coils for high-pressure boilers in the sampling of steam and boiler waters. Their generally high corrosion resistance to the impurities in boiler water and steam provides a very pure uncontaminated sample for high accuracy measurements. On the cooling water side, some of the stainless steels may show pitting especially where salt or brackish waters with industrial wastes are encountered. Even in these cases the manufacturer may be able to provide a stainless steel modified by the addition of small amounts of silver, molybdenum, copper or other elements to meet the necessities of the situation.

COPPER AND COPPER-BASE ALLOYS. Copper finds frequent application in cooling coil construction because of its generally acceptable corrosion-resistant properties coupled with its ease of being fashioned into tubular coils. It owes its corrosion resistance to the formation of a very thin, very tenacious film of cuprous oxide. In contact with solutions capable of preserving or reforming this film, copper shows remarkable resistance. Consequently it is able to resist oxygen-bearing steam condensate. On the other hand, carbon dioxide and ammonia, two common constituents in steam, can act as active corrosion agents with respect to copper. Copper sampling lines and cooling coils have been reported as satisfactory for sampling steam and boiler waters up to a temperature of 406 F. Contamination of steam samples by copper has been observed to continuously decrease to a zero or constant value at the end of a week as shown by measurement of the electrical conductivity of the condensed steam. Interruptions in the flow of the condensate were followed by renewal of the contamination until considerable flow had been re-established. When sea water containing oxygen is used as the cooling medium, copper may be superseded advantageously by the use of red brass, admiralty metal or aluminum brass as a cooling coil material of construction. On the other hand, these alloys may be subject to dezincification with acid-bearing industrial waters. There are other available copper alloys with distinctive characteristics for special cases.

NICKEL AND ITS ALLOYS. Nickel is but slightly attacked by acids, unless accelerated attack is occasioned by the presence of air or oxidizing agents. On the other hand, nickel has the ability to form a passive oxide film under certain kinds of attack. Neutral and alkaline solutions including ammonia are well resisted by nickel so that satisfactory service may be expected with most cooling waters and with neutral or alkaline boiler waters and steam condensate. Cooling water containing acid industrial wastes or acid mine waters should be questioned for use with nickel. Carbonated water may show some attack on nickel so that caution must be used in selecting nickel when steam samples are liable to contain carbon dioxide.

Monel metal, an alloy of copper and nickel, possesses ability to withstand corrosion by many media, being more resistant than nickel under reducing conditions and more resistant than copper under oxidizing conditions. Monel may be used for steam and boiler water generally. Its susceptibility to sulphurous acid makes it advisable to determine its resistance to boiler waters containing sulphite before use in sampling equipment. Since monel is resistant to hard and soft natural waters, sea water and distilled water, trouble would not be expected on the cooling side of the coil except where sea water is allowed to remain stagnant in contact with the monel metal. Monel is not highly resistant to most oxidizing acid salts and where cooling water is contaminated with industrial wastes it may be incompatible.

ALUMINUM. The stability of aluminum, a metal which is very active chemically, depends upon the

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Fig. No. 4114: Yarway Forged Steel Water Column for 900 lbs. pressure. Equipped with Yarway Vertical Gage, Fig. No. 4178, with four-glass steel insert.

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formation of a very thin adherent coating of aluminum oxide. It has been used to handle steam and distilled water, but it may not be prudent to use this metal with waters having alkalinities much above pH 8.0. A maximum temperature of 400 F is considered the limit when using aluminum with steam and hot water. Ammonia solutions do not ordinarily attack aluminum unless other salts or alkalis are present. It should not be used where salt or brackish water is used for cooling. Highly alkaline boiler waters could not be handled successfully by aluminum cooling coils. In general, it would be highly desirable to establish the suitability of aluminum by means of service tests under like conditions prior to use.

TIN. The use of block-tin condensers has long been established for condensing distilled water of high purity. Applications of tin condensers and tin-lined coils in the sampling of steam have been reported but the tin linings have been criticized as being uncertain in their protective action against contamination. Alkaline boiler waters were found to dissolve sufficient tin to adversely affect the colorimetric determination of silica.

Metals such as gold, silver and platinum are relatively corrosion-resistant under most conditions of use. Their cost precludes normal industrial use but recent advances in the technique of applying thin coatings of these metals to cheap common metals expand their availability.

Metal Combinations Used in Cooling-Coil Construction

Where cooling coil construction provides for an inner tube within which the sample is cooled and an outer tube or shell to provide flow for the cooling water, it is common practice to use copper for the outer tube while the selection of the inner tube depends upon the nature of the cooling water and the sample. Copper, stainless steel, nickel, monel and 70–30 cupro-nickel are commercially available in prefabricated cooling coils. Fittings for joining the coils to other piping are selected to avoid metal-couple corrosion. Metals used for fittings in the above cases have been bronze, brass, carbon steel, monel metal, stainless steel or cupro-nickel for the corresponding service. Naval brass fittings are considered suitable for use with 70–30 cupro-nickel.

The use of degasifiers following or integral with cooling coils is often essential in sampling and testing steam condensate.

Volume of Sample Required

The volume of sample collected must exceed the sum of the volumes required for the total number of tests to be made thereon. The individual volumes may vary, especially in the case of high-pressure boilers where the concentrations are kept at low levels. Estimates of the volume required for each of various constituents found in industrial waters are given in the A.S.T.M. Tentative Methods of Sampling Plant or Confined Waters for Industrial Uses (D 510-40 T). These are considered as merely a guide and are subject to modification consistent with directions under methods of analysis.

Apparatus has been developed for the continuous recording of such properties of the boiler water or condensed steam as pH, electrical conductivity and dissolved oxygen content. Here the sampling equipment must provide a continuous sample sufficiently cooled and especially free from contamination, because of the

high degree of sensitivity of these methods. In general, a larger volume of sample will be handled in order to reduce the time lag occasioned by travel of the sample through the sampling lines and cooling coils to the measuring and recording apparatus. If the measuring apparatus is designed to handle a small volume of sample the smaller quantity is drawn off from the main sample line by means of a tee at a point near the measuring apparatus. Short sampling lines and minimum cooling capacity with location of the measuring equipment near the point of sampling are further expedients to reduce the inherent time lag.

Sample Containers

The sample container must preserve the quality of the cooled sample, sometimes over an extended period of time; hence its construction must prevent outside contamination and at the same time avoid adding undesirable constituents by solution from within the sampling equipment. The requirements for sample containers are less stringent in respect to high-temperature reactions and the container is not exposed to the attack of the cooling water. On the other hand, the sample container may be exposed to possible attack by slow reaction of the cooled boiler water or condensed steam over a long time, resulting in the formation of corrosion products which may be sufficiently soluble to appreciably contaminate the sample, or reduce the concentration in the sample of the active corrosion agent.

Choice of material for the sample container will be governed by the nature of the water or steam being sampled, the nature and extent of the contamination by the material, and finally whether such contamination can be (1) removed subsequently, (2) quantitatively determined and correction applied or (3) completely disregarded if proved to have no effect on the property being measured.

Materials for Sample Containers

Consideration of the metals discussed for cooling coil construction indicates that the same materials may be used for sample containers under similar condition of service, with suitable attention paid to the foregoing factors pertaining specifically to the containers.

Ordinary glass may be used as a material of construction for the sample container in many cases, such as routine boiler water samples, where slight attack of the sample water on the glass over a short time is not harmful. It is noted that highly alkaline waters may dissolve silica from certain types of glass containers. One method of counteracting this solubility, where silica is being determined, is to make the sample definitely acid with a known quantity of sulphuric or other acid and later to apply the necessary corrections. For waters or condensed steam having a pH of 6.0 or over, the bottle glass should be of good chemically resistant type. Ordinary glass bottles, but not the cork, may be coated internally with paraffin to protect the sample from the glass.

The use of tin and tin-lined containers for the collection of samples of boiler water and condensed steam has been reported. Ordinary 5-gal milk cans were found to be unsatisfactory unless recoated with a heavier tin layer and the seams well sealed. Samples of condensed steam have been collected in a 500-ml silver flask closed with a silver stopper but appreciable amounts of silver

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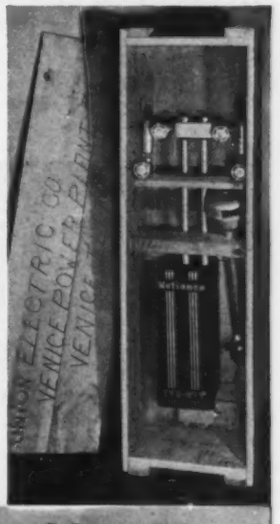

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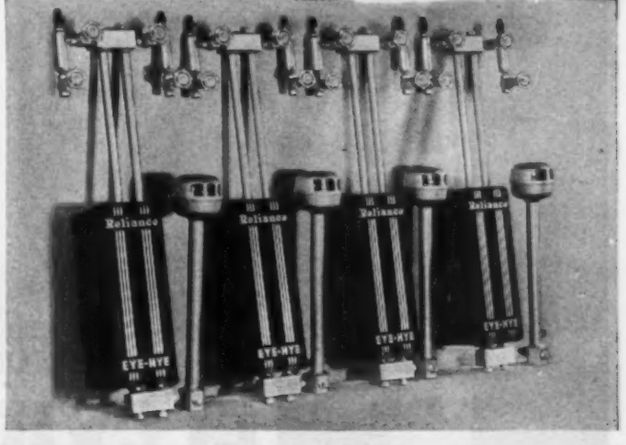

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were found in the sample. The use of platinum will generally be precluded by its cost but the development of platinum-clad metals may offer the requisite strength at a lower cost.

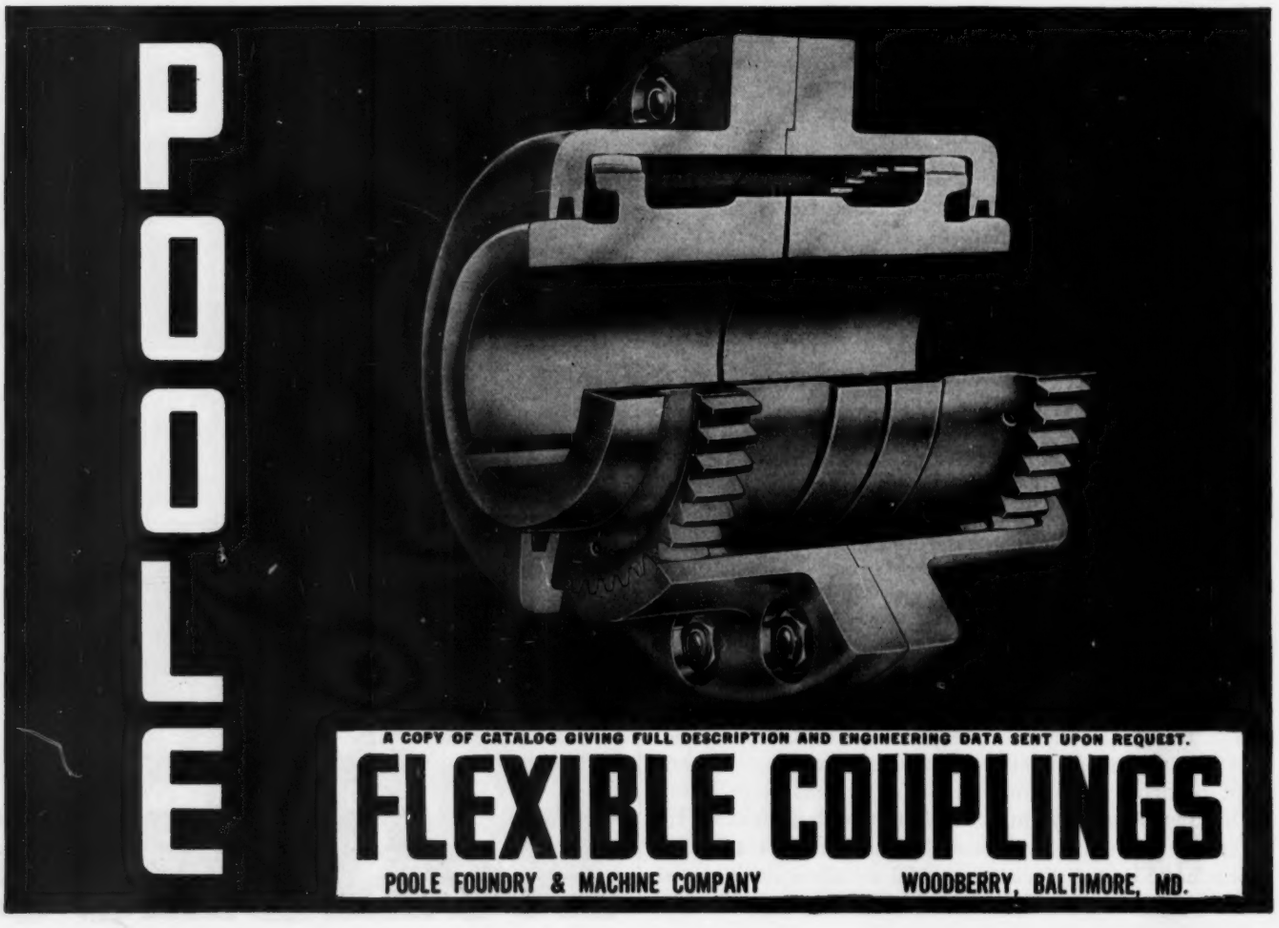
Besides the use of pure metals as a protective coating, lacquers, varnish, paraffin and other applied coatings may offer promise for protection of the base metal from corrosion and the sample from contamination. It is imperative that the coating be continuous, without pinholes and of sufficient thickness to give suitable life to the coating. Furthermore, the chemical stability of the coating must be established for the particular use. Naturally forming coatings which are self-healing in contact with the water are the best form of protection.

Conclusions

The sampling of steam and boiler water involves common-sense application of basic sampling principles to specific local problems. Choice of sampling locations, methods of sample withdrawal and volume of sample can be selected from a clear understanding of the reasons for sampling, tests to be made, accuracy necessary and similar considerations. Choice of cooling equipment becomes largely a consideration of materials of construction from the standpoints of strength, corrosion resistance and degree of sample contamination allowable. Available data on metals and alloys is not particularly specific as regards their usefulness with steam, boiler water and the various types of cooling water available.

Limited available data, plus general information on the properties of ferrous and non-ferrous materials, indicate that stainless steel, copper and copper alloys and nickel and its alloys have definite fields of usefulness in the sampling field, but a clear knowledge of the chemical constituents present in sample and cooling water is essential to proper choice of material, and discussion of the potential use with the metal producer is considered an advantageous procedure to insure correct choice. It is suggested that users of cooling coils augment the present limited data by publishing their experiences in detail and in a uniform manner. Such detail should include the following: pressure, temperature and chemical composition of the steam or water sampled; temperature, relative rate of flow and chemical analysis of cooling water; complete chemical and physical properties of metals or materials of construction; details of design of coils and their cooling capacity; type of service required of the sampling equipment.

Sampling containers may be selected in similar manner with a full understanding of requirements. The obtaining of data on the usefulness of the newer lacquer type coatings should be considered, as these may offer an economical means of preparing sample containers. Other data which would aid in proper selction of coils and containers are the limiting maximum permissible concentrations of interfering substances in each method of test.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NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Automatic Coal Scale

The Stock Engineering Company has issued a 4-page bulletin describing a recently developed 200-lb automatic coal scale for use in steam boiler plants and elsewhere. The folder illustrates design and construction features of this machine.

C-E Spreader Stoker

A new catalog, No. SS-2 describing the latest design features of the C-E Spreader Stoker, has just been issued by Combustion Engineering Company, Inc., 200 Madison Avenue, New York. This is an attractively printed twelve-page booklet which contains eighteen photographic illustrations of assemblies and typical installations, together with close-up views of the feeder, distributor, drive mechanism, and dump grate details.

Six typical setting drawings show the application of this popular method of firing to various types of boilers, including the return-tubular boiler, sectional-header and box-header boilers, the low-head three-drum boiler, and the VU type steam generator. The wide range of fuels that can be burned by this stoker is discussed and methods of cinder removal and recovery are also dealt with.

G.E. Induction Motors

Publication GEA-3580, a 12-page booklet recently issued by the General Electric Company, gives many interesting highlights on the design, construction, and application of the General Electric line of Tri-Clad motors. Particular attention is called to the motor's one-piece, cast-iron frame and end shield for protection against physical damage; the stator windings of tough Formex wire for protection against electrical breakdown; and the new design of bearings for protection against operating wear and tear. Other photographs in the leaflet show the many types of Tri-Clad motors now available and some typical industrial applications.

Packings and Gaskets

A completely new 44-page illustrated catalog of packings and gaskets, containing service recommendations and suggestions, has just been announced by Johns-Manville. In addition to detailed information on J-M packing and gasket styles, the handbook includes handy recommendation tables which serve as a guide to proper packing selection for various types of equipment under such diversified service conditions as steam, brine, ammonia, acids, caustics, and oils. An analysis of the factors which determine packing performance and helpful hints on getting the most out of packing and gaskets are given.

Butterfly Valves

A 4-page bulletin has been issued by the Henry Pratt Company describing its line of Phillips rubber seated butterfly valves. These valves may be used for gases or liquids, or for flowing solids. A dimension chart is given for valves ranging from 10 in. to 84 in. diameter.

Rubber Transmission Belts

"Selection and Maintenance of Rubber Transmission Belts" is the title of a new 12-page bulletin (Catalog Section 2150) issued by the B. F. Goodrich Company. This pamphlet presents in a simple manner the logical steps involved in answering such questions as to type, grade, width, thickness, horsepower capacity, etc., when dealing with flat rubber belting. It also deals with such topics as belt dressing, cleaning, storing, static, oil and salvage, and gives definite suggestions for maintaining belt records. This pamphlet also points out in what respects belt transmission theory has been modified as applied to modern construction of non-stretching rubber belts.

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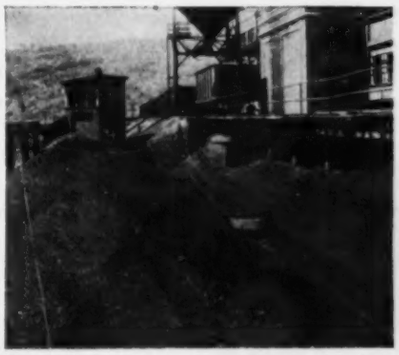
Pictured above is a 6 cu. yd. Sauerman Scraper installation handling the stockpile for an 80,000 KW. generating station. The storage area is semi-circular in shape and the scraper bucket operates on a 400-ft radius between a headpost and a self-propelled tail tower. The average handling capacity of this scraper system is 200 tons per hour, either storing or reclaiming. The total tonnage stored and reclaimed by the scraper in a twelve-month period is about 180,000 tons.



Small Sauerman Scraper Solves Another Typical Coal Storage Problem.

This illustrates a ¾ cu. yd. Sauerman Power Scraper handling coal on a long narrow strip of ground alongside a power plant. This is a small but very active storage. The minimum duty required of the scraper is to move 160 tons of stored coal per day to the bunkers. On days when coal is arriving for storage, the little scraper may handle between 300 and 400 tons, both storing and reclaiming.

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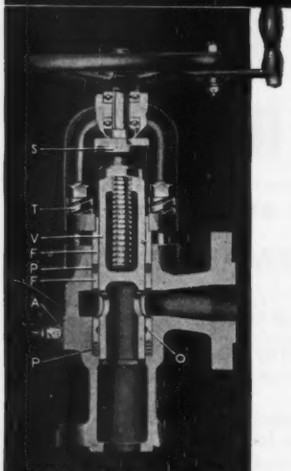

Yarway Seatless Blow-off Valve Operation. After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

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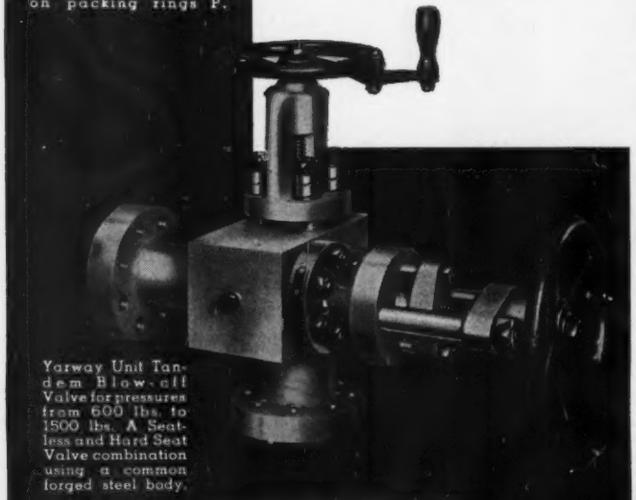

Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

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BLOW-OFF VALVES

A.S.M.E. Nominates J. W. Parker for President in 1942

James W. Parker, Vice President and Chief Engineer of The Detroit Edison Company, has been nominated for the presidency of the American Society of Mechanical Engineers, for 1942, announcement having been made at the Semi-Annual Meeting of the Society, June 16 to 19, in Kansas City, Mo.

Mr. Parker was born in Auburn, N. Y., and graduated from Cornell University with the degree of Mechanical Engineer in 1908. Following graduation he served an apprenticeship first with the DeKalb Power & Light Company and then with the Vincennes Street Railway Company, leaving in 1910 to become boiler room engineer with The Detroit Edison Company. With the exception of a year's leave of absence for service with the Ordnance Department during 1918, he has been continuously with The Detroit Edison Company in various capacities for the last thirty years. He is president of the Engineering Society of Detroit and has long been active in A.S.M.E. activities, having served both as manager and vice president.

James W. Parker

Nominations for other officers of the Society made by the regular Nominating Committee at Kansas City were as follows:

Vice Presidents: Clarke F. Freeman, Vice President, Charge Fire Prevention Engrg. & Underwriting, Manufacturers Mutual Fire Ins. Co., Providence, R. I.; Clair B. Peck, Managing Editor, *Railway Mechanical Engineering*, New York, N. Y.; William H. Winterrowd, Vice President, The Baldwin Locomotive Works, Eddystone, Pa.; Willis R. Woolrich, Dean of Engineering and Director Bureau of Engineering Research, University of Texas.

Managers: William G. Christy, Smoke Abatement Engineer, Jersey City, N. J.; Herbert L. Eggleston, Manager Gas and Refining Depts., Gilmore Oil Co., Los Angeles, Calif.; Thomas S. McEwan, Resident Manager-Engineer, McClure, Hadden & Orthan, Chicago, Ill.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Works Boiler Plant

By F. J. Matthews

This book is offered as a guide to the operation and maintenance of the small industrial boiler plant. It will appeal to operators who are studying the subject with the view to improving their status. At the same time it should be of practical value to any one engaged in boiler room engineering, assisting in correcting faults, tracing troubles, effecting economies and other problems which arise in the daily operation of the plant.

The book comprises ten concisely written chapters covering such topics as fuel factors, heat-recovery auxiliaries, heat economies, boiler feedwater treatment, operation and maintenance topics, and boiler-plant testing. The subject matter is well itemized for quick reference and is illustrated with nine halftones and eighty-eight charts and diagrams. The book contains 181 pages, size $8^1/_2 \times 5^1/_4$ in., bound in red cloth. Price $4.00.

Men and Volts—The Story of General Electric

By John Winthrop Hammond

Strange as it seems, only two generations have passed since the first arc lights spluttered on top of tall poles and the "red-hot hairpins in glass bottles" heralded the advent of the incandescent lamp. Never in all history have such strides in mastering the forces of nature been made in so brief a period.

"Men and Volts" is the story of the birth and growing pains of a great industry. Great names come to light in these pages—Edison, Thomson, Coffin, Steinmetz. Others, not so well known, gain belated recognition—"Jimmy" Wood, Frank Sprague, "Pop" Turner and "Billy" Madigan. It tells the story of the undaunted pioneers, their discoveries, their trials and their amazing successes. It tells of the origin of the General Electric Company and its development during its first thirty-odd years. But it is more than a biography of one industrial organization. It is an epic picture of the greatest period of transition in our history—the metamorphosis of the world passing from the age of labor to the new era of electrical power.

The book comprises 436 pages, including an index and many photographic illustrations and historical drawings; size 5 × 9 in., bound in grey cloth. Price $2.50.

Methods of Analysis of Coal and Coke

This book is the first 1941 American edition of a report issued by the Department of Scientific and Industrial Research which embodies the results of continued investigation into the methods for the analysis of coal and coke. The methods described were evolved primarily for use at the Department's Fuel Research Station at East Greenwich, London, England, where a high degree of accuracy is required, and are published with the object of making them available to others who may require this high standard.

These methods do not differ fundamentally from corresponding methods given in the latest specifications of the British Standards Institution but give more explanatory details, and certain methods are included for which there are at present no British Standard Specifications.

The book contains 85 pages, and includes many drawings and diagrams of the apparatus used. Size $4^1/_2 \times 8^1/_2$ in., bound in dark cloth. Price $1.50.

Sixty-Year Index

A.S.M.E. Technical Papers, 1880–1939

Ten thousand items are required to cover all of the technical papers published in *Transactions* from 1880 to 1939, and in *Mechanical Engineering* from 1908 to 1939. These items are chronologically arranged under 768 subject headings, with each article listed under as many subject headings as are required. To direct attention to related articles, 700 cross-references have been used. An author index gives the subject headings and year under which each author's paper is listed in the subject index.

The book, $8^1/_2 \times 11^1/_2$ in. in size, contains approximately 200 pages, and is bound in dark blue cloth. Price $3.75. Members' discount 20 per cent.

Report on Power Requirements

The Federal Power Commission has issued the eighth of its reports on "Electric Power Requirements and Supply in the United States" tracing the changes in the demand for power and the capacity available to meet the demand in the 48 power supply areas into which the country has been divided. The new report, which reflects month by month the impact of the expanding defense program on the country's power systems, forecasts the probable demand for electric power in each area through the remainder of 1941 and for the year 1942. It also shows the generating capacity which power systems anticipate will be available to serve the expanding load.

"In considering the forecasts, however," the report says, "it should be borne in mind that the defense program has been expanded so rapidly that estimates of future load cannot be kept completely up to date," and adds that revised estimates indicate an aggregate 1942 load approximately 1,600,000 kw in excess of the figures on which the charts in the report were based.

Copies of the report, which is designated as FPC P-7, are sold at 50 cents each by the Federal Power Commission only, to which all orders should be addressed, enclosing remittance.

Wage and Hour Manual, 1941 Edition

Out of the bewildering variety of interpretations, opinions, wage orders, rules and regulations which together comprise the so-called Wage and Hour law has come a 1100-page volume entitled 1941 Wage and Hour Manual, a book which a large number of law-harassed business executives are certain to find a guiding light in a wilderness of social legislation.

This volume supersedes a 1940 edition and contains about 500 pages more than its predecessor. It embraces, so far as can be discovered, all documentary material on Government regulation of wages and hours—the laws, administrative regulations and interpretations, and decisions of the courts. More important, the documents are arranged intelligently, fully indexed and generously interspersed with non-technical explanatory articles.

Supplementing the basic material are some 300 authoritative answers to questions on the law's application to specific cases, charts illustrating the scope of various exemptions, sample payroll forms and other devices designed to translate the law into terms understandable by the lay employer.

The volume is in three parts, the first containing 17 chapters which treat separately the overtime, minimum wage and other provisions of the Fair Labor Standards Act. In Part II similar attention is given the Walsh-Healey Public Contracts Act and miscellaneous federal laws regulating wages and hours. State legislation is treated more briefly in Part III with digests of wage, hour, child labor and industrial homework regulations for each state.

The Manual is published by the Bureau of National Affairs, Inc., and its price is $5.00.

List of Standards

The American Standards Association has published a new list of American standards for 1941, comprising more than 400 standards which include definitions, technical terms, specifications for metals and other materials, methods of test for the finished product, dimensions, safety provisions for use of machinery, and methods of work. They reach into every important engineering field and serve as a basis for many municipal, state and federal regulations. Six hundred manufacturing, government and user groups have shared in the development of these standards.

This list will be sent free of charge to anyone interested upon request to the American Standards Association, 29 West Thirty-ninth Street, New York, N. Y.

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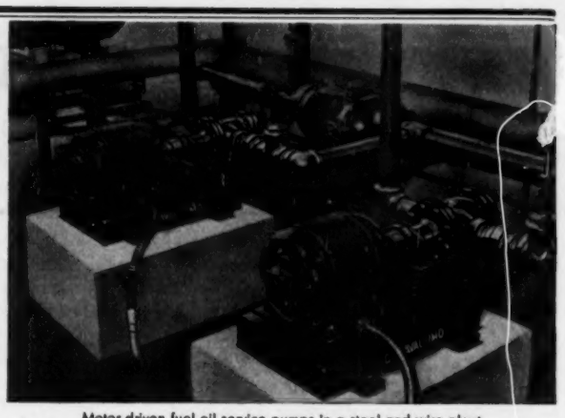

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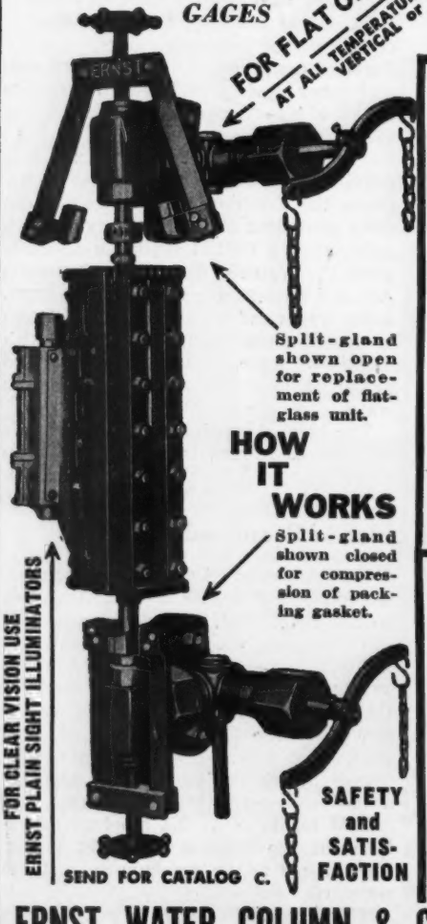

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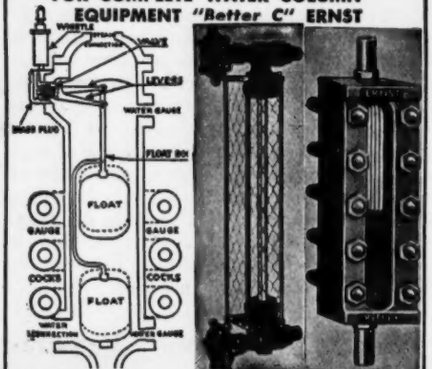

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(continued from page 44)

provement. And remember that any saving in maximum demand on system capacity is equivalent to installing just that much additional capacity, and that the benefit of this accomplishment will extend far into the post-emergency period.

2. Restudy generating plant, transmission and distribution facilities, not from the standpoint of furnishing high-quality service which utilities habitually strive to give their customers, but from the standpoint of what each part of the system can be forced to do if necessary to get the most out of the plant. The past operating history of this industry affords many examples of achievement in working plant to the limit. In general, recent years have not taxed the ingenuity of operating forces on that score, but if the occasion once more should require it, most certainly they will rise above its demands as they have done again and again in the past.

3. Keep well posted on load and capacity conditions in all neighboring territory to make additional interconnections as they may become useful in helping to assure an adequate power supply in all places and situations in and near the territory your company is serving.

4. Re-examine the several component loads which contribute to the system peak load from the standpoint of their importance to the national defense, with a view to determining in your own mind the order in which such loads could be curtailed, if real need should arise in the future, and the sensible method of accomplishing it. This proposal may sound remote and superfluous, except perhaps for a time in the water power areas affected by severe drought, but it should be remembered that this is a period when business and people are confronted with the possible imposition of restrictions in many ways affecting their lives and affairs; and, in spite of the general adequacy of power supply so far as can now be seen, it would be foolish to disregard the possibility of restrictions affecting electric service also.